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Anatomical Variations in the Female Pelvis: Their Classification and Obstetrical Significance

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Six years ago one of us [W. E. C.] instituted, at the Sloane Hospital for Women, an investigation of the influence of pelvic size and shape upon the mechanism of labour. From clinical experience it seemed apparent that certain pelvic abnormalities not adequately described in obstetrical texts played an important part in the cause of dystocia and increased the difficulty in operative delivery. We believed that if the obstetrician could appreciate the size and shape of the pelvis, it would be possible to predict the type of difficulty which might occur in labour, or to terminate the labour with less trauma to the mother and child by the use of mechanical procedures applicable to the individual case. The results of this investigation, which are briefly reviewed in this report, have proved the correctness of our original contention [1–8].

During the early months our study was directed to the large collection of skeletal material at the American Museum of Natural History, New York; the U.S. National Museum, Washington; the Hanna Museum of Western Reserve University, Cleveland; and the Department of Anatomy, College of Physicians and Surgeons, New York. It soon became apparent that the accepted obstetrical classification of pelves failed to give a true concept of the marked variation in pelvic shape which existed in skeletal material. This suggested the need for roentgenologic study of the pelvic form in living women. Hitherto no use had been made of roentgen methods of examination at the Sloane Hospital so far as pelvic shape or size was concerned. A review of the literature pointed to the use of a frame method which would outline the superior straight by the use of the semi-sitting position. This method was used in two trial cases, but the results were not satisfactory, as distortion and the lack of bone detail in the lower pelvis prevented the adequate visualization of pelvic shape which the study of skeletal material had shown to be desired. Dr. Ross Golden and Dr. Paul C. Swenson, of the Roentgen-ray Department of the Presbyterian Hospital, were consulted, and acquainted with our difficulties and our objectives. The use of stereoroentgenograms was advised, and we were thereby gratified with the three-dimensional visualization of the pelvic cavity from the inlet to the outlet. Thus, by means of a roentgenological examination, it became possible to study in conjunction with skeletal material the variations in pelvic shape in living women.

Patients who had encountered major difficulty during labour were asked to report from the post-partum clinic for roentgenologic examination, and in a short time all the various types of extreme variation in pelvic shape observed in skeletal material were found in living women. Since complete details of the difficulties encountered in the operative delivery of these patients were available, it was possible to correlate these difficulties with the size and shape of each pelvis and to demonstrate that, in certain instances, the operator had attempted an obstetrical manœuvre which was

resisted by the particular shape of the pelvis. It thus became apparent that if an acceptable classification of pelvic shape could be devised, a practical and new diagnostic approach could be made to the study of the mechanism of labour.

During the latter part of the investigation the mechanism of labour was studied by a roentgenological examination during labour. This method permitted a study of the adjustment of the head to the particular shape of the individual pelvis and revealed its axis of descent. It was possible, in many instances, to obtain a roentgenologic examination just before the termination of the labour by some form of operative delivery. These films became invaluable records of the rôle played by pelvic type from the standpoint of the proper level at which to effect anterior rotation in examples of transverse or occipito-posterior arrest of the head, and enabled us to suggest the proper position in which the head should descend through the lower pelvis. This knowledge also enabled us to develop accuracy in the prediction of the probable mechanism of labour with each particular pelvic shape.

The main results of our investigations may be dealt with under the following heads :—

(1) The technique of pelvioradiography.
(2) The classification of the female pelvis from the standpoint of morphology.
(3) The mechanism of labour common to all pelvic types.
(4) The relation of pelvic shape to head position at the pelvic brim.
(5) The practical significance of pelvic shape in relation to recognized obstetrical manœuvres :—

A. Influence of pelvic type in forceps technique.
B. Transverse arrests.
C. Posterior arrests.
D. Anterior arrests.
E. The pelvic outlet as influenced by lower sacral variations.

(6) Stillbirth and its relationship to the mechanism of delivery.

(1) The Technique of Pelvioradiography

Having demonstrated the superiority of stereoroentgenograms in portraying the morphology of the pelvis, we realized that certain improvements in the technique of obtaining the films and in their visualization in the stereoscope would increase the practical value of the examination. For instance, it was found that in the ordinary stereoscope it was possible to vary the size of the stereoscopic image markedly by slight changes in the angle of the reflecting mirrors. As a result it was difficult to determine the true size of the pelvis, even though its shape was accurately reproduced. While experimenting with methods to enable us to observe a true pelvic image, we conceived the idea of recording the cardinal diameters of the pelvis by carrying a measuring ruler into the pelvic image directly under stereoscopic vision. Further experimentation proved the practicability of this method, which in itself was already known as the measurement of the " phantom image ". The principle was originally suggested by Deville [9]. Later, Trendelenburg [10], Pulfrich [11], and others, devised complicated stereoscopes which, though accurate, were not practical for general use. Accordingly we devised a special stereoscope and made certain additions to the technique of taking stereoroentgenograms to ensure the correct placement of the films in the viewing-box of the stereoscope. This latter objective was accomplished by the use of a casette frame (fig. 1) which marks the periphery of the film with the image of arrow markers, for placement over corresponding lines on the celluloid edge of the viewing surface. The optical system was equipped with rhomboids to adjust for variations in individual interpupillary distances. The full-silver surfaced mirrors were replaced by half-platinized mirrors, to allow direct measurement of the " phantom image " under stereoscopic vision. The finished

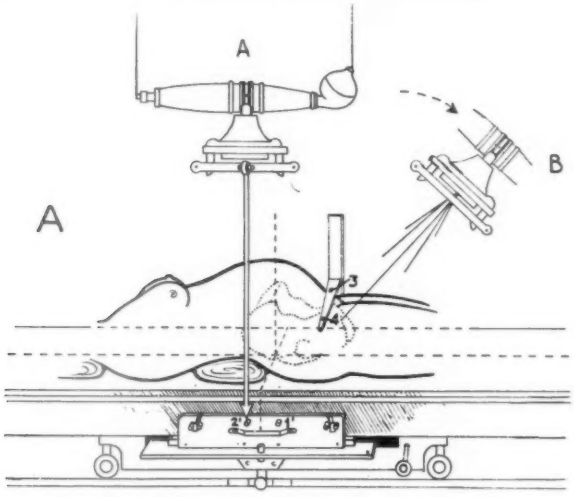
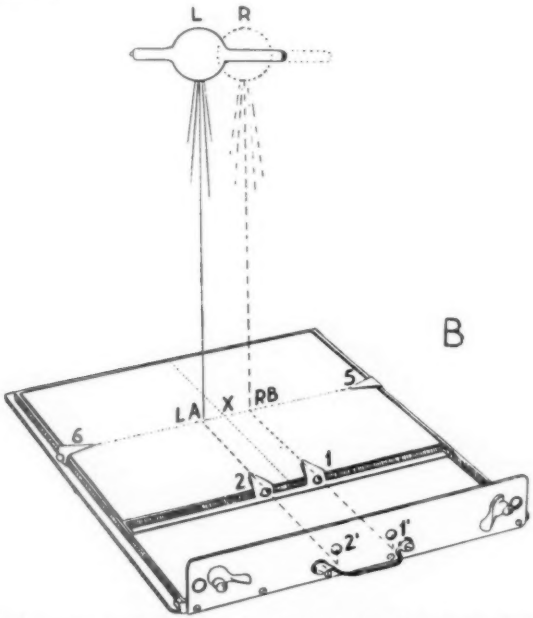


FIG. 1.—THE TECHNIQUE OF PELVIC RADIOGRAPHY

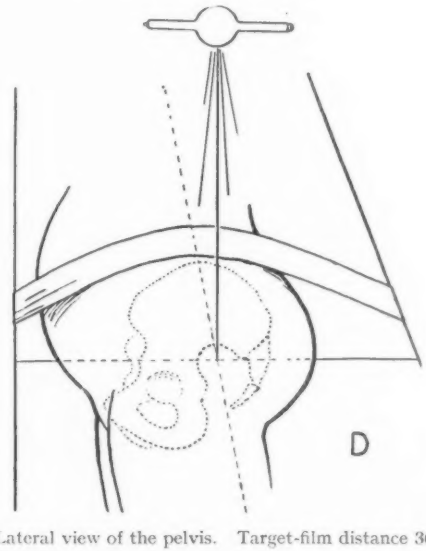
A. The patient supine on the X-ray table with the lumbosacral pad in place. The target is centred just above the mid-point of the line joining the anterior-superior iliac spines. Known marker 3 and 4 is suspended just free of the abdomen above the symphysis. B—A 45° angle view of the subpubic arch.



B. The casette frame to mark the films for placement in the viewing box of the precision stereoscope (fig. 1 c). The casette frame is placed over the casette on the casette tray and fixed by lugs to the side of the X-ray table (*see* fig. 1 A 1′ and 2′). With each shift the target moves along the line joining 5 and 6. For each exposure the target bears a perpendicular relationship to either 2 and 2′ or 1 and 1′.

model is called a *Precision Stereoscope*, because by its use the trained observer can carry an ordinary measuring rule into the pelvic image and measure directly any desired pelvic diameter at any level in the pelvis. One objective of the investigation was thus accomplished—namely a roentgenologic technique giving a three-dimensional

C. The viewing surface of the precision stereoscope. The image of the arrow-tips 5 and 6 and 2 and 1 (fig. 1 B) are made to superimpose over corresponding lines marked on the celluloid edge of the viewing box.



D. Lateral view of the pelvis. Target-film distance 36 in.

image of pelvic shape and of the relationship of the head to the pelvic inlet and at the same time enabling the observer to measure the cardinal pelvic diameters, fig. 1C. In each instance a lateral film of the pelvis is obtained and also a view of the subpubic arch (fig. 1, A and D).

(2) The Classification of the Female Pelvis from the Standpoint of Morphology

At first the inspection of skeletal material revealed such marked variations in the shape of the pelvic inlet that a classification according to type did not seem feasible, but with greater experience in the study of pelvic morphology, it became evident that certain pelves conformed to one of four characteristic inlet shapes, namely, the *long narrow oval*, the *round*, the *flat*, and the *wedge-shaped* types. A large number of pelves appeared to conform to intermediate shapes between these extreme types. It seemed advisable to consider these four characteristic extreme shapes as standard or parent types and to devise a terminology which would not only designate these types but would be flexible enough for combinations with each other to designate the equally important borderline forms.

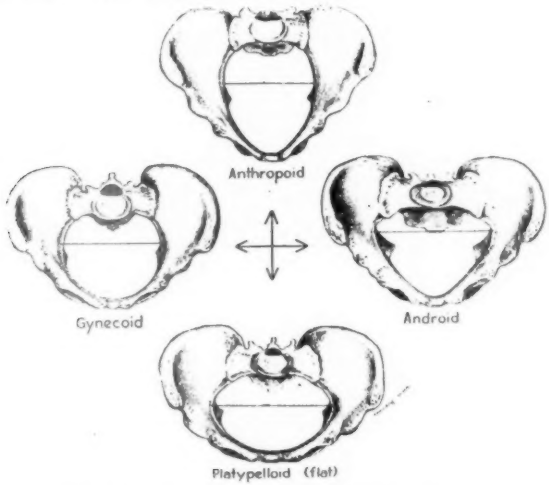


Fig. 2.—The Four Classical Pelvic Types

The four standard or parent types divided into an anterior and posterior segment by a coronal plane passing through the widest transverse diameter and the interspinous diameter. In the illustration only the widest transverse diameter is shown.

A review of the literature revealed that Weber [12] in 1830, and von Stein [13] in 1844, had recognized these four groups but had not considered the borderline types. Turner [14], in 1885, described three of these four groups but failed to suggest the wedge-shaped type and, like Weber and von Stein, did not attempt the classification of the borderline groups. The long narrow oval type appeared to resemble the pelvis of the anthropoid apes, and Turner, considering this type a primitive form, had shown it to be more commonly found in primitive races. The round type conformed to the classical female pelvis. The wedge-shaped pelvis simulated the appearance of the male pelvis. Berry Hart [15] recognized and described this type as the sexually inverted pelvis. The flat pelvis, though frequently confused with the wedge-shaped form, presented no difficulty of recognition to these earlier workers. All this information enabled us to suggest the following terminology for these four standard types (fig. 2) :—

(1) The anthropoid type, resembling the long, narrow, oval pelvis of the anthropoid ape.

(2) The gynecoid type, showing all the well-known architectural characteristics of the normal female pelvis.

(3) The platypelloid type. This pelvis has a wide or transverse oval appearance.

(4) The android type, which bears a morphological resemblance to the human male pelvis. The inlet is wedge-shaped or blunt heart-shaped.

The use of one of these terms by itself indicates a parent pelvic type in which the combined shape of the anterior and posterior segment conforms to the classical longitudinal oval (anthropoid), the round (gynecoid), the transverse oval (platypelloid), or the wedge-shaped (android) type of inlet. Many pelves are, in shape,

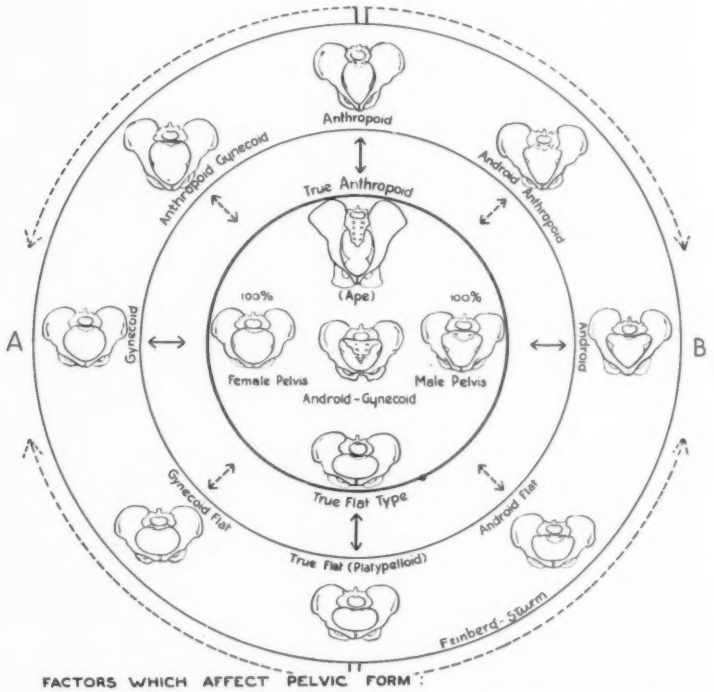


FIG. 3.—THE FOUR CLASSICAL TYPES AND INTERMEDIATE FORMS

The complete classification showing the relationship of borderline or mixed pelvic types to the standard or parent forms. Observe the transition in pelvic shape from a long narrow oval (anthropoid) through the round (gynecoid) to the flat (platypelloid) form. Pelves with masculine characters may also show a similar cycle of change.

A. Evolutionary—transition from the long oval (anthropoid) to the flat type (vertical axis).

B. Sexual—overlap of masculine characters from the gynecoid to extreme android type (trans-axis) and within the evolutionary cycle.

borderline types containing characteristics of each of these four parent groups. In the analysis and description of these we have found that great help is obtained if we divide the pelvis into an anterior and posterior segment not only at the outlet, as is commonly done, but also at the inlet and in the cavity. This division is accomplished by passing a coronal plane through the widest transverse diameter of the inlet and

the interspinous diameter. The posterior segment may conform in shape to one standard type and the anterior segment to another. By suitable combinations the terminology suggested for the parent forms may be used to describe these borderline types. The first term describes the shape of the posterior segment and the second term indicates the shape of the anterior segment. Thus the term " anthropoid-gynecoid " is intended to designate a borderline type between the anthropoid and gynecoid type which is a long *wide* oval in shape. The " gynecoid-flat " is a normal pelvis with a *flat tendency* at the inlet. The " anthropoid-gynecoid " and " gynecoid-flat " borderline types, *along with their respective parent forms*, denote a cycle of change in pelvic form from the longitudinal narrow oval through a round type to a transverse oval or flat shape, fig. 3.

Certain mixed types of pelves may show in addition masculine characteristics in the posterior pelvis, as evidenced by a narrow sacrosciatic notch or a narrow fore pelvis to form a *long narrow wedge-shaped* inlet, a *flat wedge-shaped*, or a *blunt-heart-shaped* inlet. These borderline android forms are described by the terms " android-anthropoid ", " android-flat ", or " android-gynecoid ".

The term " platypelloid ", originally suggested by Sir William Turner, is too cumbersome for general use. Accordingly it is used to designate the flat group of pelves which show variable degrees and types of flattening at the inlet, such as the " gynecoid-flat ", the " android-flat ", and the " true flat pelvis ".

Below the pelvic inlet the shape of the pelvic cavity may change, as the outlet is approached, through variations in the splay of the side walls and the curvature and inclination of the sacrum and symphysis. A decrease in transverse capacity may be caused by convergence of the side walls or variations in the length of the ischial spines. The subpubic arch may be wide, moderate, or narrow, but the size of the arch may or may not vary directly with the degree or type of side-wall convergence. As a result a narrow subpubic arch may be associated with a wide intertuberous diameter, or, on the other hand, an equally narrowed subpubic arch may be found with a narrow intertuberous and interspinous diameter (fig. 4).

Variations in the transverse and longitudinal curvature and in the inclination of the sacrum have as important effects on lower posterior pelvic capacity as the character of the side walls and the subpubic arch have upon anterior pelvic capacity. The inclination of the sacrum is shown by the angle subtended between the plane of the inlet and the surface of the upper two or three sacral segments. The inclination may be forward, average, or backward (fig. 4). A line drawn from the ischial spines to the sacrum, parallel to the plane of the inlet, gives an index of posterior pelvic capacity at that level. (Posterior sagittal diameter of the second parallel plane.) The lower sacral region, along with the coccyx and its ligamentous supports, forms a platform under the ischial spines, the so-called sacrococcygeal platform. From the practical standpoint it is important to gain information relevant to the level of this region to the spines and the position of the sacral tip in relation to the ischial spines. (Posterior sagittal diameter of the third parallel plane, fig. 4.) The practical significance of the forward or backward sacral inclination and forward or backward sacral tip, with variations in the level of the sacrococcygeal platform to the ischial spines, will be discussed by means of suitably chosen case studies.

All these anatomical variations can be determined with fair accuracy by clinical examination of the pelvis. The clinician carefully palpates the subpubic arch, determines the slope of the side walls down to the ischial tuberosities, and notes the character of the ischial spines and the relationship of the sacrococcygeal platform to the ischial spines. At higher levels the upper sacral region or sacral promontory may be palpable. Under such circumstances the application of the facts gained from the palpation of the lower pelvis to the supposed shape of the inlet will reveal the pelvic type within a practical degree of accuracy. The clinical recognition of a pelvic abnormality justifies a roentgenologic examination, in order that the obstetrician may

gain a detailed knowledge of the shape and size of the pelvic cavity in each individual case.

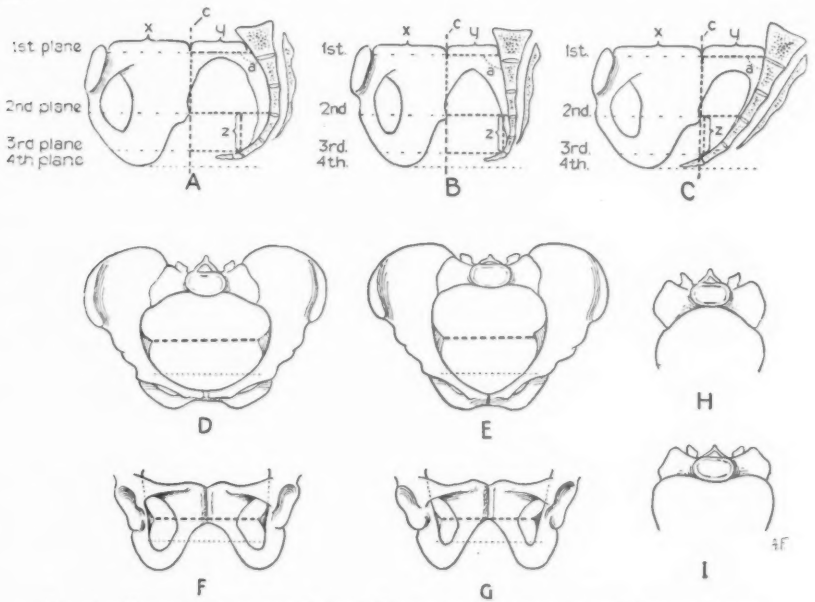


FIG. 4.—VARIATIONS IN THE LOWER PELVIS AS RELATED TO THE PELVIC INLET

c = a coronal plane through the widest transverse diameter of the inlet and the interspinous diameter divides the pelvic cavity into an anterior and a posterior segment.

x = anterior sagittal diameter at inlet and to lower levels.

y = posterior sagittal diameter at inlet and to lower levels.

a = the inclination of the sacrum as indicated by the size of the angle subtended between the first parallel plane of the inlet and the surface of the upper two or three sacral segments.

A. Increased sacral curvature and backward sacral inclination. Note length of posterior sagittal diameter, " y " at the inlet (first parallel plane), at the level of the ischial spines (second parallel plane), and at the level of the sacral tip (third parallel plane). The fourth parallel plane denotes the lowest portion of the pelvic cavity at the ischial tuberosities. Observe level of sacro-coccygeal platform " z " to the ischial spines. (This description applies also to B and C.)

B. Straight sacrum, average sacral inclination.

C. Average curvature to sacrum ; forward sacral inclination.

D, E, F, and G. Case studies to show that equally narrowed subpubic arch views may be associated with pelves of different shapes. The pelvis of D and F shows a wide interspinous and intertuberous diameter. The pelvis of E and G shows a narrow interspinous and intertuberous diameter with converging side walls.

H. The transverse sacral concavity commonly found in anthropoid types.

I. The straight sacral edge commonly found in android and flat types.

We established the frequency of occurrence of the four standard types in skeletal material from the inspection of Professor Todd's fine collection of sexed pelves at Western Reserve University. The borderline forms were included in the nearest related standard type (Table I).

TABLE I

Type	Female white %	Female negro %
Anthropoid	23·5	40·5
Gynecoid	41·4	42·1
Platypelloid	2·6	1·7
Android	32·5	15·7
No. of cases	147	121

The anthropoid type, as Turner pointed out, is more commonly found in the negro race. The android type is more frequently observed in the white race. The platypelloid type, though rare, is twice as common in the white race as in the black.

The frequency of occurrence of these pelvic types varies according to race, to constitutional habitus or selection of groups within each race, and to familial and other inherited characteristics.

Summary of Classification and Description of the Pelvis

I. The anthropoid type (pure or parent type)—large, average, or small.
II. Intermediate or mixed types between the anthropoid and gynecoid types—large, average, or small : anthropoid-gynecoid type.
III. The gynecoid type (pure or parent type)—large, average, or small.
IV. Intermediate or mixed types between the gynecoid and platypelloid (flat) types—large, average, or small : gynecoid-flat type.
V. The platypelloid type (pure or parent type)—large, average, or small.
VI. The android type (pure or parent type)—large, average, or small.
VII. Intermediate or mixed android types—large, average, or small : (*a*) android-anthropoid ; (*b*) android-gynecoid ; (*c*) android-flat.
VIII. Asymmetrical pelves.
IX. The pathological pelvis (rickets, osteomalacia, congenital anomalies, and deformities due to sacro-iliac and spinal disease), &c.

In addition to a complete description of the pelvic cavity from inlet to outlet, the lengths of the cardinal pelvic diameters should be given, as obtained by roentgen pelvimetry : as, for instance, the true conjugate diameter, the widest transverse diameter of the inlet, the interspinous and the intertuberous diameter. The intertuberous diameter may be obtained by the precision stereoscope, since the widest space just above the tuberosities of the ischium is easily located.

In each individual pelvis the following regions of the lower pelvis must be described in detail :—

(*a*) Subpubic arch—wide, moderate, narrow.
(*b*) Pubic rami—straight or curved. (Gothic or Norman arch effect.)
(*c*) Splay of side walls—divergent, straight, or convergent.
(*d*) Fore pelvis—well formed or funnel-shaped.
(*e*) Character of the ischial spines—long and narrow, or flat on a broad base.
(*f*) The sacrosciatic notch—wide, average, or narrow masculine type.
(*g*) The sacrum—a general concept of length, width, curvature, and number of segments.
(*h*) Sacral inclination—forward, average, backward.
(*i*) Lateral bore—straight, convergent, or divergent.
(*j*) The posterior sagittal diameter, at the inlet, at the level of the ischial spines and at the level of the sacral tip and the relationship of the sacrococcygeal platform to the plane of the ischial spines.
(*k*) Shape of the outlet in front of the sacral tip.

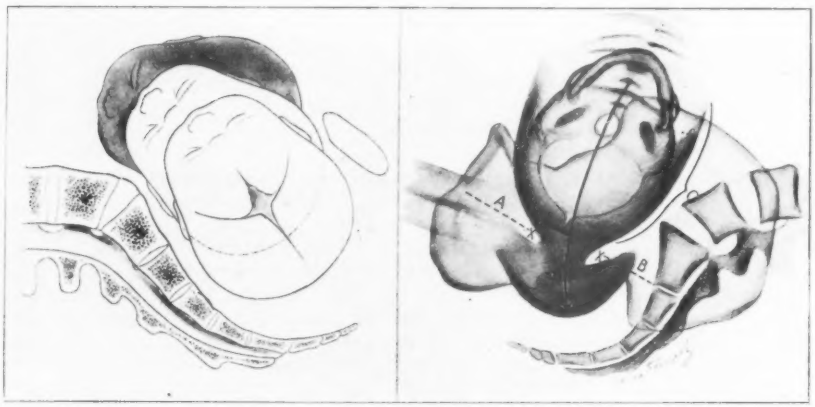
Finally the pelvis should be studied as a whole, to determine whether it is well formed or angular, irrespective of the gynecoid, android, anthropoid, or flat character of the pelvic inlet.

(3) The Mechanism of Labour Common to All Pelvic Types

As soon as the marked variation in pelvic shape had been noted and a classification of pelves devised, the roentgenological method of examination was used extensively during labour to study the position and axis of descent of the head in relation to the

pelvic cavity at various levels. Attention was first directed to engagement and descent.

The act of engagement in normal labour is illustrated diagrammatically in fig. 5 A and B. In most cases engagement begins with the head assuming a moderate degree of asynclitism or showing a tendency towards a posterior parietal presentation. The posterior parietal bone overhangs the inlet with the sagittal suture directed downward and forward. The anterior parietal bone descends behind the symphysis in a *downward and backward direction* until the head is fitting squarely in the pelvic canal. The lower uterine segment and cervix, while dilating in active labour, serve as a guiding factor during engagement. Scant reference has been made in recent obstetrical literature to the importance of this factor. Barnes [16] described the principle quite accurately by stating that the anterior aspects of the lower uterine segment acted



A B

FIG. 5.—ENGAGEMENT OF THE HEAD WITH VARIATION IN THE POSITION OF THE AXIS OF DESCENT.

A. Common mechanism of engagement. The posterior parietal bone overhangs the inlet with the sagittal suture directed downward and forward. The anterior parietal bone descends behind the symphysis in a downward and backward direction following a curved axis of descent.

B. The method of engagement illustrated in fig. 5 A takes place along the axis of the curved area. Variations in the length of AX and BX may bring about descent close to the symphysis or to the sacrum.

as a "valve" or "inclined plane" directing the head downward and backward. Parvin [17] and others inferred the mechanism when they spoke of a "dynamic" axis of descent caused by soft parts which did not always correspond with the so-called "static" axis of the pelvis itself.

The roentgenologic study of the fœtal pelvic relationships during labour shows also marked variations in the position of the axis along which this act of engagement takes place (fig. 5 B). A decrease in the length of AX brings about descent of the head close to the symphysis. A decrease in the length of XB causes descent to occur close to the sacrum. Therefore the position of the head may vary according to the shape of the segment through which it descends. The cause for these variations in axes of descent is open to speculation. In certain instances abnormalities in pelvic size and shape may be the causative factor. In others the length, strength, or character of the supports of the lower uterine segment and the cervix may force the head to descend through the fore pelvis or through the posterior pelvis.

(4) The Relation of Pelvic Shape to Head Position at the Pelvic Brim

This was studied by means of stereoroentgenograms and lateral views of the pelvis obtained early in labour in approximately 200 unselected cases. The observations are shown in Table II.

Table II

	Posterior oblique position %	Transverse position %	Anterior oblique position %	Direct occipito-anterior position %	No. of cases
Anthropoid	28·5	37·5	17·0	17·0	59
Gynecoid	10·0	69·0	20·0	1·0	81
Android	20·5	71·0	8·5	0·0	59
Combined	18·5	60·0	16·0	5·5	
					Total 199

Most obstetrical texts state that the oblique anterior position is more commonly found at engagement than either the transverse or oblique posterior position. This table shows, however, that transverse positions are three times as common as the other positions. The influence of pelvic shape at the inlet is also shown. In gynecoid and android types transverse positions occur in approximately 70% of the cases. In anthropoid types the long narrow inlet causes a decrease in transverse positions (37·5%) and a marked increase in anterior positions (34%) and posterior positions (28·5%). The head must descend and engage before the shape of the inlet can exert the maximum influence upon its position. During engagement, however, it is not unusual to observe partial rotation as the head adjusts itself to the shape of each particular pelvis. At lower levels a roentgenological examination obtained later in labour has shown that partial rotation from the transverse to the posterior position may occasionally occur if the shape of the lower pelvis creates increased capacity in the sacral hollow, or if the fore-pelvis becomes narrow by converging side walls. As a rule, however, in spontaneous deliveries, the position assumed by the head at engagement is maintained to a low level in the pelvis before anterior rotation begins. Thus the transverse position in android and flat pelves represents a physiologic position for these particular pelves. Likewise, the oblique anterior and posterior positions may be considered normal for the anthropoid pelvis.

In a case of arrest it is evident that a knowledge of pelvic shape will enable the obstetrician to determine whether it is advisable to maintain the position of arrest to lower levels, to rotate at the level of arrest, or to elevate and rotate at higher levels in the pelvis.

(5) The Practical Significance of Pelvic Shape in Relation to Recognized Obstetrical Manœuvres

Obstetrical prognosis and the management of labour depend upon a number of factors, the more important of which deal with the questions of whether the head *will* descend and of *how* the head descends. The question of whether the head *will* descend concerns the problem of disproportion between the size of the head and the pelvic inlet. Disproportion between the head and the pelvis, to even a major degree, is occasionally observed in spontaneous deliveries, especially in multiparous women. The incidence of variable degrees of disproportion increases in the low forceps, low-medium and medium forceps, and Cæsarean section groups. The disproportion, in most instances, can be readily observed from the study of the stereo-roentgenograms in the precision stereoscope by visually attempting to compare the head and its biparietal diameter with the available space present at the inlet or in the lower pelvis. The observer experienced in the use of the precision stereoscope can actually measure one or more cardinal diameters of the fœtal head, besides noting the amount of clearance between the head and the pelvis. Flexion and moulding of the head in

labour decrease head size and represent such variable factors that attempts to reduce the degree of existing disproportion to simple mathematical terms have not given satisfactory practical results. Although a roentgenological examination may reveal the pelvic type and the presence of a large head, a trial of labour becomes the best means for determining the correct significance to place upon this supposed degree of disproportion.

The question of *how* the head descends when the pelvis is abnormal has considerable practical significance, especially in regard to the ease or difficulty encountered in the use of certain recognized obstetrical manœuvres, either manual or instrumental.

The influence of pelvic type on the method employed for delivery is shown in Table III.

TABLE III.—DISTRIBUTION OF PELVIC TYPES ACCORDING TO THE METHOD OF DELIVERY.

							Platypelloid				
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Gynecoid	Android	Android-gynecoid	Gynecoid-flat	Android-flat	True-flat	Rachitic-flat	No. of cases
Spontaneous	10	15	9	37	10	8	5	4	2	0	100
Low forceps	16	15	10	32	16	5	3	2	1	0	100
Low-mid forceps	13	10	12	12	21	14	5	9	4	0	100
Mid forceps	12	2	12	15	35	9	6	8	1	0	100
Cæsarean section	11	5	9	12	41	7	3	6	2	4	100
									Total	..	500

The most significant fact revealed by this table is the frequency of spontaneous deliveries in the gynecoid forms and the frequency of forceps deliveries and Cæsarean section in the android forms. The efficiency of the anthropoid pelvis is demonstrated by the decrease in incidence of this type and its borderline forms from the spontaneous to the Cæsarean section group. In 500 cases four rachitic flat pelves were noted, all in the Cæsarean section group.

Average measurements on a group of anthropoid, gynecoid, or flat pelvic types will show a ratio between the antero-posterior and the widest transverse diameters which indicates a long narrow oval, a round, or a transverse oval shape. The characteristic wedge-shaped appearance of the android type, however, is not shown by the ratio between these diameters. Accordingly no attempts were made to compute average measurements, since the results would not be significant in revealing pelvic shape.

The smaller the pelvis, the greater is the chance of obstetrical difficulty. This well-known fact is evident in Tables IV to VIII, which show an increased frequency of small diameters from the spontaneous to the Cæsarean section group. But the high frequency of small diameters in low-medium and medium forceps cases shows that small diameters do not preclude the possibility of safe delivery through the natural passages. Safe delivery under such circumstances may depend upon the efficiency of the forces of labour or the use of mechanical skill in operative deliveries when the pelvis is abnormal. It is for this reason that interest is directed toward pelvic shape in relation to recognized obstetrical manœuvres.

Tables IV to VIII also show that pelves of various types may be associated with a small pelvic diameter. Flat pelves with an antero-posterior diameter of 10 cm. are

TABLE IV.—DISTRIBUTION OF SMALL DIAMETERS ACCORDING TO PELVIC TYPES IN 100 CASES OF SPONTANEOUS DELIVERIES OF THE AVERAGE SIZE CHILD (3,200 GRM.).

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
A.P. diameter of 10 cm. or under	0	0	0	0	0	1	2	0	1	4
Interspinous diameter of 10 cm. or under	7	2	4	1	2	2	0	0	0	18
Transverse less than 12 cm.	2	0	0	0	0	0	0	0	0	2

TABLE V.—DISTRIBUTION OF SMALL DIAMETERS ACCORDING TO PELVIC TYPE IN 100 CASES OF LOW FORCEPS DELIVERIES.

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
A.P. diameter of 10 cm. or under	0	0	0	0	0	0	2	2	1	5
Interspinous diameter of 10 cm. or under	11	4	5	1	1	10	0	0	0	32
Transverse less than 12 cm.	3	1	1	1	0	1	0	0	0	7

TABLE VI.—DISTRIBUTION OF SMALL DIAMETERS ACCORDING TO PELVIC TYPE IN 100 CASES OF LOW-MID FORCEPS DELIVERIES.

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
A.P. diameter of 10 cm. or under	0	1	0	2	0	0	2	5	1	11
Interspinous diameter of 10 cm. or under	9	7	7	6	1	12	2	4	0	48
Transverse less than 12 cm.	5	3	3	1	0	0	0	0	0	12

TABLE VII.—DISTRIBUTION OF SMALL DIAMETERS ACCORDING TO PELVIC TYPE IN 100 CASES OF MEDIUM FORCEPS DELIVERIES.

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True flat	Number of cases
A.P. diameter of 10 cm. or under	0	0	1	2	0	2	2	3	0	10
Interspinous diameter of 10 cm. or under	6	3	8	6	4	17	0	1	0	45
Transverse less than 12 cm.	5	0	2	0	0	1	0	0	0	8

TABLE VIII.—DISTRIBUTION OF SMALL DIAMETERS ACCORDING TO PELVIC TYPE IN 100 CASES OF DELIVERY BY CÆSAREAN SECTION.*

							Platypelloid				
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Rachitic-flat	Number of cases
A.P. diameter of 10 cm. or under	0	2	2	1	4	15	1	6	0	4	35
Interspinous diameter of 10 cm. or under	9	2	6	1	6	27	0	2	0	0	53
Transverse under 12 cm.	6	1	2	0	1	5	0	0	0	0	15

* In Tables IV to VIII the increased frequency of narrow diameters from the spontaneous to the Cæsarean section group indicates that the pelvis also decreases in size. In the tables many pelves had more than one small diameter.

commonly found in the spontaneous and low forceps group. However, certain android, gynecoid, anthropoid-gynecoid, or android-anthropoid types may have an equalled narrowed antero-posterior diameter but may require medium forceps or Cæsarean section to effect delivery. The same principle is noted when a small interspinous diameter is compared to pelvic type and the method employed for delivery. Certain anthropoid types with a small interspinous diameter are found in the spontaneous and low-forceps groups. But the android pelvis is commonly associated with an equally narrowed interspinous diameter in the medium-forceps and Cæsarean-section groups. In anthropoid types the long antero-posterior diameter may compensate for the narrow interspinous diameter, but in android types there is less compensatory space in the sagittal plane or in other regions of the pelvis. These observations show that as pelvic form is so variable, any single small diameter is not an index of pelvic capacity. We believe the visual study of stereoroentgenograms is the best method of examining the pelvic architecture, since the narrowest diameter can be seen and measured and the compensatory space can be noted in other diameters.

(5A) *Influence of Pelvic Type in Forceps Technique*

It has been noted that in certain instances the head may descend through the posterior pelvis close to the sacrum, through the centre of the pelvis, or through the anterior pelvis close to the symphysis (fig. 5 B). During this present investigation no attempt has been made to determine the frequency of occurrence of these axes of descent. But in the spontaneous and the forceps group numerous instances showed that with efficient labour in an abnormal pelvis the head descends more easily through the ample posterior pelvis. In low-medium and medium arrest of the head, the proximity of the head to either the sacrum behind or the symphysis in front has complicated the mechanism of forceps delivery. Granted that the axis of descent may guide the head close to the symphysis or to the sacrum, it follows that arrest may occur with the head close to the symphysis in one case, or closer to the lower sacral region in another. For this reason it is suggested that when the position of arrest in relation to the symphysis or sacrum can be accurately ascertained by clinical or roentgenological methods of examination, the type of forceps operation should be classified as " low-medium or medium forceps through the anterior pelvis *in front* " or " low-medium or medium forceps through the posterior pelvis *behind* ", or by the use of some other equally descriptive term (fig. 6 A).

With arrest of the head in the transverse position, manual or instrumental anterior rotation brings about a mechanical advantage only if the shape of the upper pelvis will allow rotation, or if anterior rotation is advisable from the standpoint of the shape of the pelvis below the level of arrest (fig. 6 B).

The head may become arrested close to the symphysis or pubic rami in the position designated as "low-medium or medium forceps in the anterior pelvis". In these cases manual or instrumental methods should be used first to elevate the head and then to direct it slightly downward and backward and thereby avoid misdirected force with traction against the fore pelvis (fig. 6 D).

Most experienced obstetricians have encountered cases in which anterior rotation by manual or instrumental methods is difficult or impossible to accomplish. In such circumstances numerous manœuvres may be used with success—such as pelvic application of forceps to the transverse position, oblique application, or a cephalic application of Kielland forceps. In skilled hands good results are obtained by any of these manœuvres. We feel that stereoscopic examination of the pelvis has enabled us to choose the best method applicable to the particular case. In our clinic we have been favourably impressed by the use of Barton forceps [19] in the treatment of transverse arrest of the head (fig. 6 C). According to the type of pelvis, the Barton forceps may be used to rotate the head at the level of arrest or to effect descent to lower levels without rotation. If it is desirable to bring the head to a lower level in

the transverse position (low-medium or medium forceps in posterior pelvis *behind*, fig. 6 A), the head is made to descend by lateral flexion following the curve of the lower sacrum and sacrococcygeal platform. By this act the influence of the posterior pelvis is removed and anterior rotation can be easily accomplished on the inner aspects of the pubic rami or with the caput in sight below the subpubic arch.

The principle of descent advised for the treatment of transverse arrest of the head, and illustrated in fig. 6 C, may be applied to other positions of the occiput. The occipito-posterior position may be used as an example. In the discussion of the observations shown in Table II, we pointed out that the occipito-anterior and the occipito-posterior position seemed to be normal positions for the head to assume in anthropoid types for the same reason that platypelloid and android types favoured

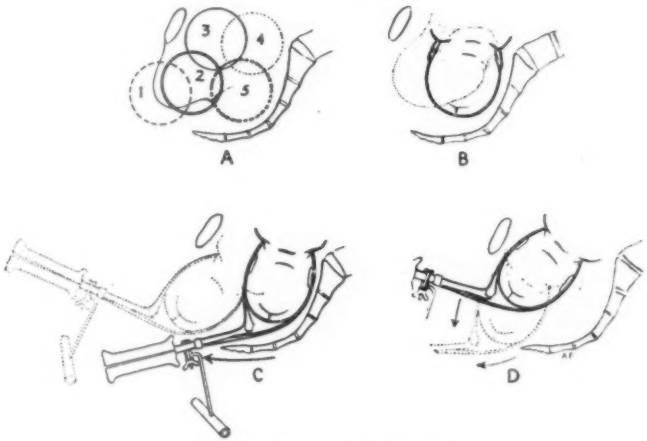


FIG. 6.—FORCEPS TECHNIQUE

A. Classification of forceps from the standpoint of level and axis of arrest.
1. Low forceps.
2. Low-medium in the anterior pelvis (in front).
3. Medium in the anterior pelvis (in front).
4. Medium in the posterior pelvis (behind).
5. Low-medium in the posterior pelvis (behind).

B. This diagram shows the mechanical advantage of anterior rotation from the transverse position if the shape of the pelvis will allow rotation. By anterior rotation the occiput approaches closer to the symphysis in the fore pelvis.

C. A head arrested in the transverse position in the posterior pelvis may be delivered to lower levels in the position of arrest by anterior lateral flexion. Barton forceps are applicable for this mechanism. The head is made to follow closely the curve of the lower sacrum and coccyx. Anterior rotation is accomplished on the inner aspects of the pubic rami or in the subpubic arch.

D. Arrest of the head may occur close to the posterior aspects of the symphysis and pubic rami. Forceps may be difficult to apply. The head is elevated and deviated slightly downward and backward as illustrated and later laterally flexed as in fig. 7 D.

descent in the transverse position. Accordingly in the treatment of arrest of the head in the occipito-posterior position, in certain instances it may be advisable for the obstetrician to bring the head to lower levels and effect rotation on the pelvic floor or occasionally, if the shape of the pelvis so demanded, to deliver face to pubis. In other instances the best manœuvre may be to elevate the head to a higher level and rotate there. This is especially true when the pelvis is of the anthropoid type with marked transverse narrowing throughout.

Let us amplify these general statements by a more detailed study of cases.

(5B) *Transverse Arrests*

In 48 cases out of 100 medium-forceps deliveries the head was found arrested in the transverse position. The type of pelvis associated with the particular obstetrical manœuvre employed to effect delivery is shown in Table IX. In 22 instances the

TABLE IX.—DISTRIBUTION OF PELVIC TYPE ACCORDING TO THE MANŒUVRE USED IN MID-PELVIS ARREST IN THE TRANSVERSE POSITION.
(48 *in* 100 *Cases of Mid Forceps.*)

	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Platypelloid: Gynecoid-flat	Platypelloid: Android-flat	Platypelloid: True-flat	Number of cases
Barton's, pelvic or cephalic application in the O.T. with traction to pelvic floor followed by low rotation	0	1	1	4	2	7	2	5	0	22
Anterior rotation with forceps at level of arrest	0	1	4	0	1	4	2	0	0	12
Manual rotation to oblique anterior position with delivery by pelvic curved forceps	1	0	0	0	1	3	0	1	0	6
Spiral anterior rotation by forceps	0	0	0	1	1	5	0	0	0	7
Elevation with anterior rotation and forceps	0	0	0	0	0	0	1	0	0	1
								Total	..	48

delivery was accomplished by the cephalic application of forceps (usually Barton forceps) to the transverse position, with lateral flexion, descent to the pelvic floor in the same position, and low anterior rotation. Two types of pelves are characteristically responsible for the ease of this mechanism—the android with straight side walls and the flat type of pelvis (fig. 7 A and B). In the android pelvis resistance to anterior rotation is offered by the flat posterior pelvis. The presence of straight side walls indicates good transverse diameters throughout the lower pelvis. Lateral flexion removes the influence of the posterior pelvis and allows anterior rotation to occur on the inner aspects of the pubic rami or at a low level in the subpubic arch The act of anterior lateral flexion will frequently effect actual descent without the use of strong axis traction force. Barton forceps are used to illustrate this mechanism (fig. 7 C, D, and E). After anterior rotation has been accomplished, Barton forceps are removed and the delivery is terminated by the cephalic application of pelvic curved forceps (fig. 7 F).

In the classical flat pelvis the transverse oval at the inlet is preserved throughout lower levels by means of straight side walls and an average curvature and inclination to the sacrum (fig. 7 B). This transverse oval shape predisposes to a transverse mechanism throughout the pelvis, which becomes more important for ease in labour the greater the degree of flattening, provided the inlet admits the head. Less trauma to mother and child results if the head is made to descend to lower levels in the transverse position, as illustrated in fig. 7 C, D, E, and F.

The pelvis may show variable degrees and types of flattening. In the true flat pelvis the side walls do not converge and so the ischial spines are not prominent. Nor are they so in the normal pelvis with slight flattening, the so-called gynecoid-flat. The same mechanism occurs in the android-flat pelvis, but in this type there may be convergence of the side walls with increased prominence of the ischial spines. Prominent ischial spines may cause lateral sulcus tears in the vagina if the flattening of the inlet is sufficiently marked to prevent early anterior rotation of the head in an

effort to avoid the spines. Separation of the symphysis, stillbirth, a shocked infant, or serious injury to the maternal soft parts, has occurred from failure to maintain this transverse mechanism and from making premature attempts at anterior rotation in certain android and flat pelvic types.

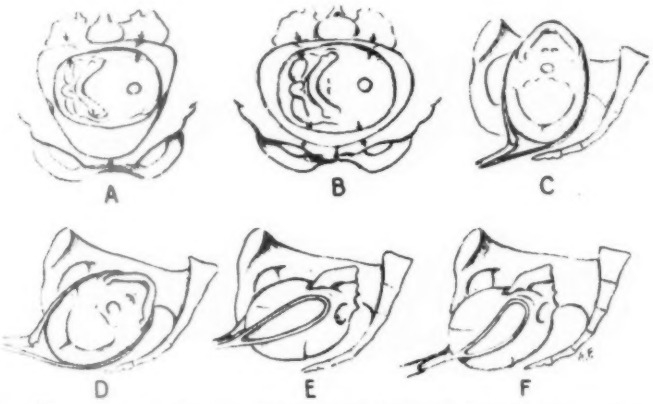


FIG. 7.—THE MECHANISM IN ANDROID TYPES WITH STRAIGHT SIDE WALLS, AND IN THE FLAT TYPE OF PELVIS

A. Anterior rotation is resisted by the opposing forces between the head and the flat posterior pelvis in certain android types.

B. Anterior rotation is resisted by opposing forces between the head and the posterior and anterior walls of the pelvis in flat forms.

C. Barton forceps applied to the head.

D. Descent with lateral flexion. The head follows the curve of the lower sacrum and coccyx.

E. Anterior rotation is effected at a low level on the inner aspects of the pubic rami or under the subpubic arch after the head has been deviated away from the influence of the posterior pelvis.

F. Barton forceps are removed and a cephalic application of pelvic curved forceps made for the low terminal delivery.

Table IX also shows that ease in anterior rotation in transverse arrests of the head usually indicates ample space in the antero-posterior diameter to allow this rotation. There is a decided decrease in flat types in the cases in which anterior rotation is accomplished by manual or instrumental rotation at the level of arrest.

This table also shows that anterior spiral rotation with descent is commonly associated with a particular type of android pelvis (fig. 8). The inlet in characteristic android types is wedge-shaped, because of the flat posterior pelvis and the narrow angle of the fore-pelvis behind the symphysis. There is also a definite degree of convergence, with prominent ischial spines and a narrow subpubic arch. Although architecturally the inlet cannot be considered flat, the antero-posterior diameter is usually under average in size and the narrow angle to the fore pelvis creates a flat space in the posterior pelvis through which the head descends. Thus transverse arrest at, or slightly below, the level of the ischial spines is likely to occur. In the operative delivery the shape of the upper pelvis acts to maintain this transverse position, while the changed shape of the mid-pelvis, caused by the narrow interspinous diameter, tends to encourage anterior rotation so that the head may make use of the compensatory space in the sagittal plane at this level. Further descent in the transverse position will bring the head into contact with the restricted interspinous diameter. The correct mechanism in the event of transverse arrest in this type, therefore, consists of anterior lateral flexion associated with spiral rotation and descent (fig. 8). In reality this mechanism consists of anterior lateral flexion, which deviates the head

toward the pubic rami and away from the posterior pelvis. After this position has been obtained, anterior rotation may be more easily carried out. Occasionally further descent in the transverse position must be carried out, when anterior rotation is prevented by the flat shape of the posterior pelvis at higher levels. As a result we have found several examples of android types with convergence of the side walls in which delivery was terminated by the use of Barton forceps. In these cases Barton forceps served to flex the head laterally in the transverse position into the fore-pelvis away from the influence of the posterior pelvis. The head descends to a lower level in the transverse position through the widest part of the anterior pelvis (intertuberous diameter) in front of the narrow interspinous diameter. Anterior rotation is accomplished according to the principle illustrated for the flat mechanism in fig. 7. The typical android pelvis (fig. 8) represents, in our experience, the only

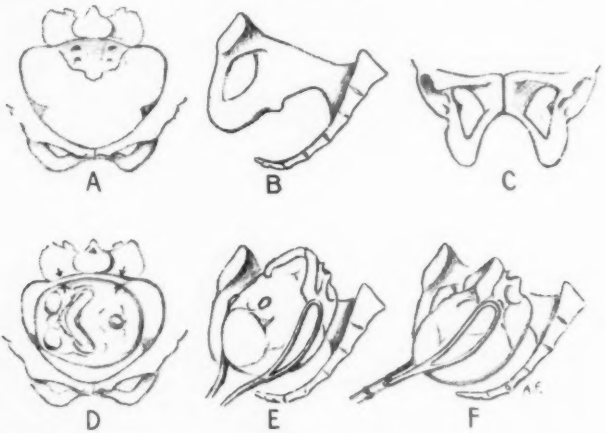


FIG. 8.—THE MECHANISM OF SPIRAL ANTERIOR ROTATION IN TYPICAL ANDROID TYPES

A. Inlet view to show the wedge-shaped inlet with converging side walls.

B. Lateral view to show the slightly restricted capacity in the posterior pelvis.

C. View of the narrow subpubic arch.

D. Transverse arrest of the head in mid-pelvis. The shape of the posterior pelvis prevents easy anterior rotation of the head. The narrow interspinous diameter with converging side walls below require anterior rotation, in order that the biparietal diameter may descend through the intertuberous diameter and the long axis of the head may adjust itself to the sagittal diameter.

E. Pelvic curved forceps effect partial rotation and carry the head away from the posterior pelvis by lateral flexion. With descent anterior rotation continues as the head moves downward and forward.

F. Anterior rotation is now completed with the vertex low on the pelvic floor.

type in which this spiral anterior rotation with descent is applicable. It is a mechanism which must be employed with care. Version and breech extraction has occasionally been used to effect delivery in similar cases. It is difficult to study the mechanism in this form of pelvis, because in our series such types have commonly been delivered by Cæsarean section.

The examples shown in fig. 7 illustrate the head close to the sacrum descending through the posterior pelvis (as in the low-medium or medium forceps *behind*, fig. 6 A). Other examples will be found in which the head descends through the fore pelvis close to the symphysis (as in the low-medium and the medium forceps *in front*, fig. 6 A). This type of fore pelvic arrest may occur in any type of pelvis which presents a flat surface to the lateral aspects of the fœtal head. The mechanism of delivery is shown

in fig. 9 in association with an android-gynecoid type of pelvis. The android-gynecoid type has compensatory space in the wide, well-formed fore pelvis. In the upper pelvis the shape of the posterior segment creates a transverse position. If the ischial spines are long and the interspinous diameter is slightly narrowed, the head not infrequently descends diagonally downward and forward to pass in front of the ischial spines and utilize the wide intertuberous diameter in the lower fore pelvis. The close approximation of the lateral aspects of the head to the well-formed fore pelvis helps to maintain a transverse position to a low level and resists manual attempts at anterior rotation. In the delivery an attempt must be made first to elevate and flex the head laterally away from the symphysis before anterior lateral flexion and anterior rotation may occur. By these manœuvres misdirected force against the pubic rami is avoided.

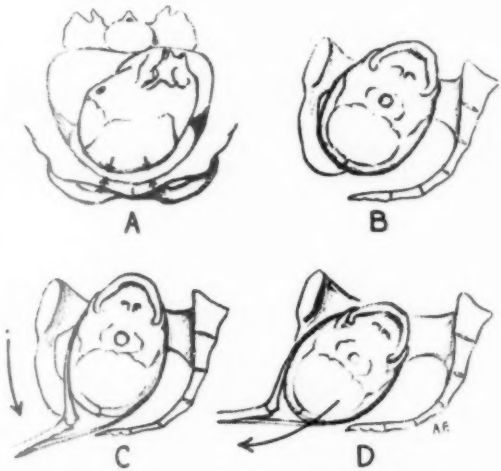


FIG. 9.—THE MECHANISM WITH ARREST IN THE FORE PELVIS CLOSE TO THE SYMPHYSIS AND DESCENDING PUBIC RAMI

A. Arrest in the fore pelvis in the transverse position in an android-gynecoid type. Anterior rotation is resisted by the flat surface of the fore pelvis. (The head may present close to the symphysis in any position.)

B. Lateral view with transverse position illustrated. The lateral side of the head tends to be close to the posterior aspects of the symphysis.

C. The head is dislodged upward and then slightly downward and backward by manual or instrumental methods.

D. By lateral flexion the head descends into the outlet and under the subpubic arch where anterior rotation is carried out.

Mid-pelvic arrest in the transverse position occurred in eight pelves of the anthropoid type. In six of these cases the ample antero-posterior diameter allowed anterior rotation at the level of arrest. This manœuvre is advisable in an effort to avoid forceful descent of the head in the transverse position through a transversely manœuvred pelvis. Occasionally this latter mechanism may be used if anterior rotation is resisted by the posterior pelvis or if the shape of the outlet favours descent of the head in the transverse position. However, in most instances, transverse arrest of the head in typical anthropoid types should not be delivered to lower levels in this position. Separation of the symphysis, with stillbirth, has occurred when such incorrect mechanical methods were used to effect delivery.

The method of delivery for the low-medium type of arrest in the transverse position and the type of pelvis commonly associated with each manœuvre is shown in Table X.

TABLE X.—DISTRIBUTION OF PELVIC TYPE ACCORDING TO THE MANŒUVRE USED IN DELIVERY IN LOW MID-PELVIC ARREST IN THE TRANSVERSE POSITION.
(29 *in* 100 *Cases of Low-mid Forceps.*)

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
O.T. to floor (Barton forceps). Low rotation	0	0	0	0	2	2	2	4	2	12
Rotation to O.A. manually plus low forceps	0	0	0	1	2	5	1	0	1	10
Anterior rotation with forceps	0	0	0	1	3	0	1	1	1	7
								Total	..	29

It will be observed again that when low transverse arrest occurs in association with the flat type of pelvis, Barton forceps are used to effect lateral flexion and low rotation. Manual rotation to the anterior position is successful if the pelvis shows compensatory space in the antero-posterior diameter. Occasionally, even in flat types, arrest may occur at a very low level after partial anterior rotation has occurred spontaneously. In these examples a cephalic application of pelvic curved forceps is made to complete the rotation.

It is interesting to note that in no instance was low transverse arrest of the head found in any pelvis possessing an anthropoid or long oval shape. Low transverse arrest and its relationship to the flat pelvis is quite analogous to the low occipito-posterior arrest of the head in relation to the anthropoid type of pelvis.

(5c) *Posterior Arrests*

In 31 cases, out of 100 medium-forceps deliveries, the head was found in the occipito-posterior position, Table XI. In approximately one-half of these cases

TABLE XI.—DISTRIBUTION OF PELVIC TYPE ACCORDING TO THE MANŒUVRE USED IN THE DELIVERY IN MID-PELVIC ARREST IN THE OCCIPITO-POSTERIOR POSITION.
(31 *in* 100 *Cases of Mid-forceps Deliveries.*)

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
Rotation to O.T. and descent to floor. Low rotation	3	0	3	2	1	4	1	2	0	16
O.P. to floor. Pelvic application	2	0	1	1	0	0	0	0	0	4
Face to pubis	1	0	0	0	0	0	0	0	0	1
Scanzoni at level of arrest	2	0	0	0	0	2	0	0	0	4
Manual rotation at level of arrest	0	0	0	0	1	0	0	1	0	2
Elevation with manual rotation	0	0	1	0	0	0	0	0	0	1
Spiral rotation with descent	0	0	0	0	0	2	0	0	0	2
Craniotomy	0	0	0	0	0	1	0	0	0	1
								Total	..	31

delivery was accomplished by manual rotation to the transverse position followed by the application of Barton forceps. By lateral flexion and traction the head

descended to a lower level in the transverse position, where anterior rotation was performed similar to the flat mechanism illustrated in fig. 7. The common pelvic type corresponded to the android form with slight convergence of the side walls (fig. 10). The slight convergence caused the shape of the mid-pelvis to approach a

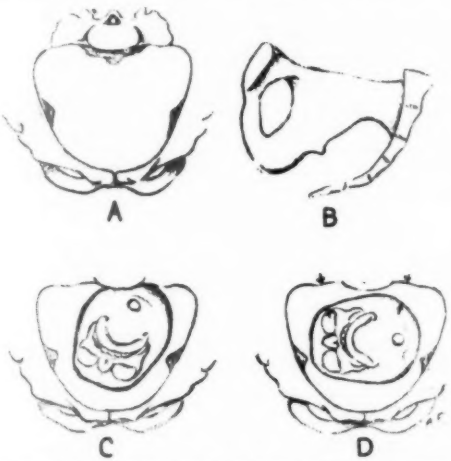


FIG. 10.—THE MECHANISM OF ARREST IN THE OCCIPITO-POSTERIOR POSITION IN ANDROID TYPES WITH SLIGHT CONVERGENCE

A. Inlet view to show the shape of the inlet with slight narrowing of the fore pelvis and slight convergence of the side walls.

B. Lateral view.

C. Arrest in the occipito-posterior position at mid-pelvis. The shape of the pelvis aids in causing this position.

D. The flat posterior pelvis prevents rotation of the ovoid head beyond the transverse position. From this position this delivery is usually terminated by Barton forceps as shown in fig. 7.

long oval type. The flat posterior pelvis prevented complete anterior rotation beyond the transverse at the level of arrest.

A flat tendency in the pelvis was present in three cases in which it was noted that a good sacral concavity allowed the occiput to rotate posteriorly (fig. 11). In these flat types it is obviously desirable to make use of the wide transverse diameter by rotating the head to a transverse position and by maintaining this position to a lower level according to the flat mechanism illustrated in fig. 7. The android-anthropoid type was present in three cases in which the flat posterior pelvis resisted anterior rotation. In one extreme anthropoid pelvis rotation to the transverse position, with descent to a lower level in this position, represented poor mechanics. In another extreme anthropoid this transverse mechanism was necessary because the outlet had a flat shape due to a markedly forward sacrum.

A Scanzoni manœuvre was performed in four cases with small babies: two in anthropoid types and two in android forms. The Scanzoni manœuvre is too well known to require illustration.

A pelvic application of forceps to the occipito-posterior position, with traction to a lower level, was made in four cases, in three of which the pelves were anthropoid types (fig. 12). In all these cases there was a convergence of the side walls which also helped prevent anterior rotation. Descent to lower levels in the occipito-posterior position should not be attempted if the lower sacrum is forward. In one extreme anthropoid the child was delivered, face to pubis.

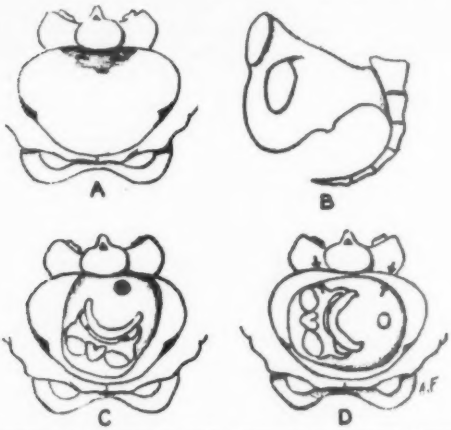


FIG. 11.—THE MECHANISM OF ARREST IN THE OCCIPITO-POSTERIOR POSITION IN FLAT TYPES WITH A BACKWARD SACRUM

A. Inlet view.

B. Lateral view to show the backward inclination to the sacrum with increased sacral concavity into which the occiput rotates.

C. Arrest in the occipito-posterior position in mid-pelvis.

D. As in the android type, fig. 10, the posterior pelvis prevents rotation of the ovoid head beyond the transverse position. From this position delivery is usually terminated by the use of Barton forceps as illustrated in fig. 7.

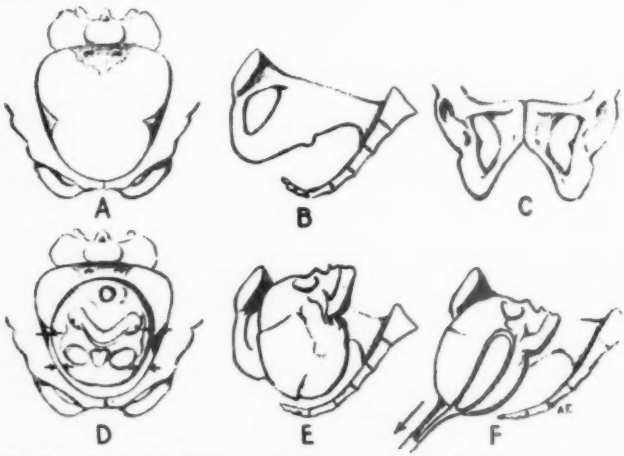


FIG. 12.—THE MECHANISM FOR DELIVERY FROM ARREST IN THE OCCIPITO-POSTERIOR POSITION TO LOWER LEVELS IN THE SAME POSITION

A. Android-anthropoid type of pelvis with a long antero-posterior diameter, prominent ischial spines, and converging side walls.

B. Lateral view to show ample posterior pelvic capacity because of an average curvature and inclination to the sacrum.

C. Antero-posterior view of the slightly narrowed subpubic arch.

D. Arrest in the occipito-posterior position—inlet view.

E. Arrest in the occipito-posterior position—lateral view.

F. A pelvic application of pelvic curved forceps is made and traction exerted downward and forward. A low complete rotation may be accomplished with caput in sight, or the head may be delivered occasionally face to pubis if the lower sacrum does not offer obstruction.

Manual rotation at the level of arrest was successful in one case with a normal pelvis. Elevation of the head with rotation at a higher level was also employed on one occasion in an android-anthropoid type. Spiral rotation with descent was employed in two android types. Craniotomy—through poor judgment—was performed in one instance.

Thoms [18] and others have drawn attention to the frequency of occurrence of the occipito-posterior position in the anthropoid pelvis. This observation, of course, is correct, but the anthropoid pelvis is an efficient pelvis, and there is usually spontaneous rotation or arrest in the occipito-posterior position at a low level with the caput in sight. A study of Table XI, however, indicates that in medium-forceps deliveries the arrested posterior position is found chiefly in android or in flat pelves. The long oval shape is present at the mid-pelvis, to encourage this position by the presence either of converging side walls in the android type or of a backward sacrum in the flat forms. This observation is important and stresses the value of a knowledge of pelvic shapes in the treatment of mid-pelvis arrest.

In the low-mid type with arrest of the head in sight or on the pelvic floor, however, we find that the occipito-posterior position becomes once more characteristic of the anthropoid pelvis, as shown in Table XII. 15 of the 22 cases showed extreme

TABLE XII.—DISTRIBUTION OF PELVIC TYPES ACCORDING TO THE MANŒUVRE USED IN THE DELIVERY OF LOW MEDIUM ARREST IN THE OCCIPITO-POSTERIOR POSITION.

(22 in 100 *Cases of Low-mid Forceps.*)

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
Complete Scanzoni	5	0	0	0	0	1	0	0	0	6
Complete manual anterior rotation	2	1	0	2	0	1	0	0	0	6
Manual to O.T. plus Barton's	0	0	1	1	1	0	1	0	0	4
Face to pubis ..	0	0	1	0	0	0	0	0	0	1
Elevation with manual rotation	2	0	1	0	0	0	0	0	0	3
O.P. to lower levels. Low rotation	1	0	1	0	0	0	0	0	0	2
									Total ..	22

anthropoid tendencies with definite transverse narrowing throughout the pelvis. Descent of the head to the outlet usually implies good flexion and moulding; accordingly, anterior rotation is much more easily carried out than it would be if arrest took place at a higher level. Complete forceps rotation (Scanzoni manœuvre) was performed six times at this low level of arrest, and in five instances the pelvis was anthropoid in shape. Elevation with manual rotation of the well-flexed and moulded head was successful three times in anthropoid types. The method used commonly in mid-pelvic arrest in the transverse position was used only four times in the 22 cases of the low-medium type, i.e. manual rotation to the transverse position, with application of forceps, lateral flexion and descent, with anterior rotation with the caput well in sight. Face-to-pubis delivery with forceps was easily accomplished in one case in which there was a marked android-anthropoid type with convergence.

In an extreme anthropoid type one stillbirth resulted after arrest had occurred with the caput in sight in the direct occipito-posterior position (fig. 13). The baby was injured by repeated attempts at anterior rotation. The successful manœuvre consisted in elevation of the head to the inlet with manual rotation. This particular patient has subsequently delivered an average-sized child, face-to-pubis, spontaneously, this fact indicating that in certain cases delivery by forceps, face-to-pubis, is justifiable.

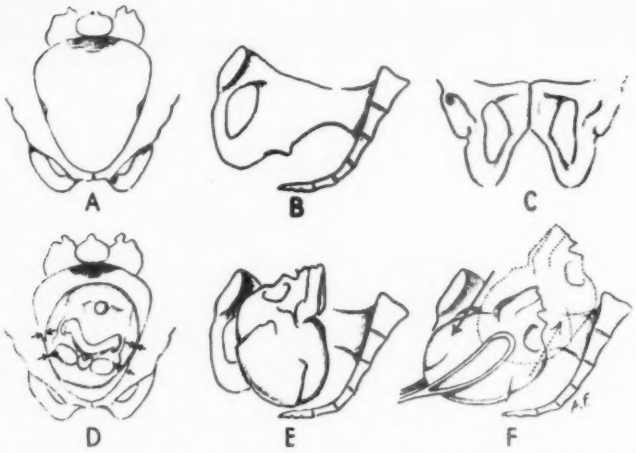


FIG. 13.—THE MECHANISM OF ELEVATION WITH HIGH MANUAL ROTATION OF THE OCCIPITO-POSTERIOR POSITION IN EXTREME ANTHROPOID TYPES

A. Inlet view showing a long antero-posterior with marked transverse narrowing through the pelvis.

B. Lateral view indicating a slightly forward lower sacrum.

C. Antero-posterior view of the narrow subpubic arch.

D. Arrest in the occipito-posterior position in the lower fore pelvis with caput in sight. Attempts at anterior rotation at the level of arrest were unsuccessful because of the restriction in transverse diameters. These attempts at rotation seriously injured the child, causing a stillbirth.

E. Lateral view of arrest in the occipito-posterior position.

F. Delivery was finally accomplished easily by elevation of the head toward the inlet followed by manual anterior rotation at this high level. The head rapidly descended to the outlet where forceps were applied.

(5D) *Anterior Arrests*

The type of pelvis associated with mid- and low-mid arrest in the anterior position is shown in Table XIII. The first point of interest is the absence of flat pelves in the medium-forceps group. This finding contrasts with that of occipito-posterior mid-pelvic arrest, in which the flat pelvis was occasionally noted in conjunction with a backward sacrum. The anterior position, however, as in the occipito-posterior arrest, is associated with two common architectural features, i.e. an ample antero-posterior diameter and converging side walls with a decrease in the interspinous diameter.

TABLE XIII.—DISTRIBUTION OF PELVIC TYPES IN ARREST IN THE ANTERIOR POSITION FOR MID- AND LOW-MID FORCEPS DELIVERIES.

(*From* 100 *Cases each of Mid and Low-mid Forceps.*)

							Platypelloid			
	Anthropoid	Anthropoid-gynecoid	Android-anthropoid	Android-gynecoid	Gynecoid	Android	Gynecoid-flat	Android-flat	True-flat	Number of cases
Mid-pelvic arrest in the anterior position delivered by cephalic-application of forceps	3	0	5	2	4	7	0	0	0	21
Low-mid arrests in the anterior position delivered by cephalic application of forceps	3	9	8	9	4	12	0	4	0	49

With arrest of the head in the anterior or the anterior oblique position a cephalic application of forceps is easily made and the degree of traction necessary to effect delivery is, to a certain extent, dependent upon the degree of convergence of the side walls. The widest biparietal diameter of the head descends through the intertuberous diameter in front of the narrowed interspinous diameter.

(5E) *The Pelvic Outlet as Influenced by Lower Sacral Variations*

Convergence of the side walls and variations in sacral curvature and inclination may effect a change in pelvic shape at and below the level of the ischial spines. The importance of convergence of the side walls has been repeatedly stressed in a discussion of the mechanism of forceps deliveries in the android and anthropoid types.

In the sagittal plane variations in the curvature and inclination of the sacrum affect the relationship of the lower sacrum and sacrococcygeal platform to the ischial spines and change the shape of the pelvic outlet (fig. 4 A, B, C). The frequency with which the forward sacrum was noted in the low-medium and medium forceps groups indicates the influence that restriction of posterior outlet space plays in pelvic arrest. An attempt has been made to illustrate the common types of lower sacral variation by the use of suitably chosen case studies.

In fig. 14 A, B, and C, the lower sacrum curved forward to a considerable degree below the level of the ischial spines. The long posterior sagittal diameter at the level

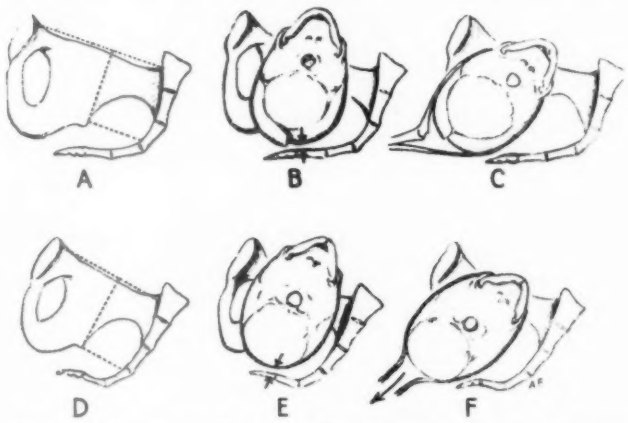


FIG. 14.—THE PELVIC OUTLET AS INFLUENCED BY SACRAL VARIATIONS

A. Lateral view of a large anthropoid pelvis with a forward lower sacrum. The posterior sagittal diameter at the level of the spines is long. The sacrococcygeal platform is elevated toward the level of the spines. The sacral tip and coccyx extends forward under the spines causing a short antero-posterior diameter at the outlet and a flat outlet shape.

B. Arrest of the head in the transverse position on the sacrococcygeal platform. The posterior parietal bone is depressed.

C. Barton forceps were easily applied. The head was flexed laterally toward the outlet and anterior rotation was accomplished after the biparietal diameter had passed the sacral tip.

D. Lateral view of an ample flat type of pelvis with good sacral concavity and forward lower sacral tip.

E. Arrest of the large head occurred on the sacrococcygeal platform close to the sacrum. The good sacral concavity allowed descent to this level.

F. Barton forceps brought the head close to the pubic rami by lateral flexion. With traction, force was misdirected against the symphysis. Barton forceps were removed and pelvic curved forceps were applied, in cephalic application. The head easily descended by downward and forward traction. Anterior rotation occurred after the biparietal diameter of the head had passed the sacral tip.

of the spines and the generally large pelvis allowed rapid descent until the head was arrested by the forward sacral tip. The shape of the outlet was converted into a flat transverse oval, which necessitated the delivery of the head to a lower level in the transverse position by forceps, as illustrated.

In the example shown in fig. 14 D, E, and F, a somewhat similar shape existed at the outlet. The pelvis conformed to a large flat type, which predisposes to a transverse arrest. The good sacral concavity and ample posterior sagittal diameter at the level of the spines allowed the head to descend to be arrested by the forward sacral tip. It was necessary to deliver the head in the transverse position through the fore pelvis until the biparietal diameter had passed the sacral tip before anterior rotation could be obtained. Barton forceps were used to flex the head laterally over the pelvic outlet close to the pubic rami. Barton forceps, however, failed to bring about descent, because force with traction was misdirected against the pubic rami. After a cephalic application was obtained by pelvic curved forceps, the correct downward and forward axis of traction was determined, and the head descended in the direction indicated in the diagram, fig. 14 D, E, and F.

The example shown in fig. 15 A, B, and C, reveals the significance of increased

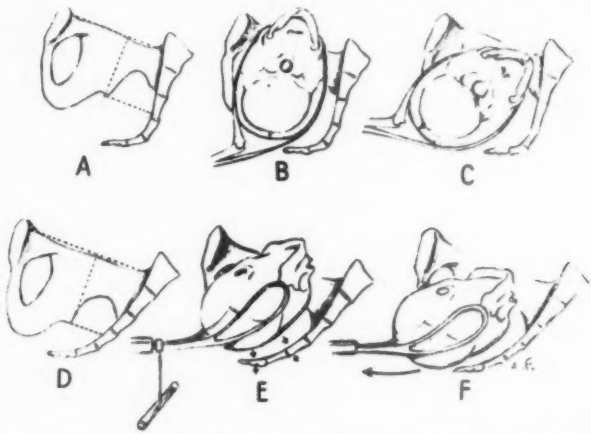


FIG. 15.—THE PELVIC OUTLET AS INFLUENCED BY SACRAL VARIATIONS

A. Lateral view of a flat android type of pelvis. The sacrum is straight with a slight backward inclination. The long posterior sagittal diameter at the level of the spines and the straight sacrum presented no obstruction to the descent of the head. Arrest occurred on the pelvic floor in the OP–OT position because the shape of the pelvis prevented anterior rotation.

B. Lateral view of the arrest, with Barton forceps applied.

C. Lateral flexion with forceps removed the influence of the posterior pelvis and allowed low anterior rotation.

D. Lateral view of an ample anthropoid type with a forward inclination to the sacrum.

E. Arrest occurred just above the pelvic floor in the oblique anterior position because of the forward sacrum. Haig Ferguson forceps were applied. A downward and backward traction caused no advance of the head because traction force was misdirected against the lower sacrum.

F. Elevation of the handles of the forceps caused slight extension of the head and with a downward and forward axis of traction descent occurred easily.

posterior outlet space caused by a straight sacrum with a slightly backward inclination. The pelvis, a flat android, allowed the head to descend in the ROT–ROP position until the posterior aspects of the perineum began to bulge. The shape of the pelvis prevented rotation, but the adequate posterior pelvic shape caused by the straight backward sacrum allowed this low descent. The patient was delivered by low forceps.

Barton forceps brought about anterior lateral flexion, and anterior rotation was easily accomplished with caput in sight.

The influence of the forward sacral inclination is shown in fig. 15 D, E, and F. The head was arrested in the direct antero-posterior position on the pelvic floor. Attempts at delivery with pelvic curved forceps failed when traction was exerted downward and backward. Force was misdirected against the forward sacrum. As soon as an attempt was made to extend the head, descent and an easy delivery occurred.

(6) Stillbirth and its Relationship to the Mechanism of Delivery

Sixteen stillbirths occurred in this series of 500 case studies. In addition four stillbirths occurred from delivery in other institutions. A detailed discussion of the factors in the maternal pelvis, the maternal soft parts, and the fœtus which contribute to the cause of the stillbirth is beyond the scope of this investigation. In three instances a larger second child was delivered spontaneously. In seven cases a major degree of disproportion existed in addition to the soft part dystocia or any incorrect axis of traction or forceful attempts at rotation. However, in nine cases, from the standpoint of pelvic shape, the mechanism used to effect delivery is open to question. Forceful attempts at anterior rotation in flat and android types represented the common errors in mechanism. We have already described the mechanism to be preferred in these types and have advised descent to the floor in the transverse position with low rotation (fig. 7). In one case-study, illustrated in fig. 13, the stillbirth was caused by forceful attempts at anterior rotation of an occipito-posterior position arrested with caput in sight in an extreme anthropoid type of pelvis with restriction in all transverse diameters. In order to illustrate more clearly the importance of using good mechanics in delivery in an effort to avoid injury to the child and the maternal soft parts, the following four case studies have been chosen.

I.—The pelvis conformed to the typical flat android type. Arrest occurred in mid-pelvis in the transverse position. The child was seriously injured by forceful attempts at anterior rotation with a poor cephalic application to the oblique anterior position. This type of pelvis favours the transverse mechanism illustrated in fig. 7. The second child was delivered spontaneously, weight 4,020 grm.

II.—(Not included in the series of 500 cases.) The pelvis conformed to the true platypelloid type. Forceful attempts at anterior rotation of an arrested transverse position caused a separation of the symphysis and a stillbirth. The second child was delivered by Cæsarean section. This pelvic type also favours the flat mechanism illustrated in fig. 7.

III.—The pelvis conformed to the typical android, with practically straight side walls. Arrest of a large child occurred in mid-pelvis in the transverse position with the cervix fully dilated. Weight of child, 3,856 grm. Forceful attempts were made to gain anterior rotation with pelvic curved forceps. The child died from intracranial hæmorrhage twelve hours after delivery. This type of pelvis favours the transverse mechanism illustrated in fig. 7.

IV.—The pelvis conforms to the typical extreme anthropoid with straight side walls and a moderate subpubic arch. Arrest occurred in low mid-pelvis in the occipito-posterior position. Forceful attempts at anterior rotation were used. With difficulty the head was rotated to the transverse position and delivered to lower levels in this position with Barton forceps. (This mechanism is obviously incorrect. The head should be elevated and rotated or brought to lower levels in the position of arrest.) The child weighed 3,610 grm., and was discharged living. It was badly shocked on delivery and suffered multiple fractures of the parietal bone.

These four cases, along with the example illustrated in fig. 13, stress the following principles in mechanism :—

(1) Forceful attempts at anterior rotation in flat and certain android pelvic types should not be made, or separation of the symphysis or stillbirth may result.

(2) The transverse mechanism to lower levels should be encouraged in these forms.

(3) Forceful attempts at anterior rotation in low occipito-posterior arrest in extreme anthropoid pelves are equally dangerous.

(4) The head should be elevated and rotated at a higher level or brought to a lower level in the occipito-posterior position and rotated or delivered face-to-pubis.

During the last two years at the Sloane Hospital for Women the attending staff have coöperated in the application of a knowledge of pelvic shape to the mechanism of labour. The incidence for Cæsarean section has not increased, because of the better selection of cases for this method of delivery. The incidence of difficult forceps deliveries has decreased, and there has been a definite decrease in the fœtal mortality, due, we believe, to the use of a better mechanism in forceps deliveries. The resident and interne staff, readily grasp, under instruction, the principles of mechanism described in this report. Recently in our clinic there has been renewed interest in the roentgenologic study of the pelvis and the fœtal-pelvic relationships of patients in labour who are not progressing normally. Frequently the recognition of a large head in a small pelvis has aided in the decision regarding the best method of delivery during the so-called trial of labour. If a forceps delivery later becomes necessary, the operator has an opportunity to attempt the mechanism he has interpreted as representing the optimum method for delivery from the study of the roentgenograms. As a result, greater conservatism in operative obstetrics has been practised.

ACKNOWLEDGMENTS

In conclusion, we wish to express our gratitude to Dr. B. P. Watson and the staff of the Sloane Hospital for Women, New York, for the co-operation extended during this investigation.

Illustrations.—Fig. 1 is reproduced by courtesy of the *American Journal of Roentgenology* and Messrs. Thomas Nelson and Sons, and fig. 2 also by courtesy of Messrs. Nelson.

Fig. 3 and figs. 5–15 inclusive, are reproduced by courtesy of the *American Journal of Obstetrics and Gynecology.*

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Discussion.—Professor F. J. BROWNE said that the four types of pelvis described by Dr. Moloy were only rarely found—gradations between them being numerous. The gynecoid pelvis was rare and almost always there were slight abnormal characters—such as some acute angulation of the fore-pelvis, or slight narrowing of the sacro-sciatic notch—indicating male tendencies. Dr. Moloy had emphasized the influence of the pelvic architecture on presentation and position of the fœtus and on the mechanism of labour, and there was no doubt it had an important bearing on these points but it could not be the sole influence, since it was repeatedly found that whereas in a first pregnancy and labour the fœtus might occupy a posterior position, perhaps giving rise to difficult labour, during the next pregnancy the position would be anterior and the labour easy. He thought too that the relative frequency of the four types of pelvis described by Dr. Moloy would be found to differ materially in England and America—an impression which had been borne out by results of investigations in London. Dr. Moloy had made no mention of the generally contracted pelvis, which was a very frequent cause of difficult labour in London. The work of Dr. Caldwell and Dr. Moloy had resulted in a great simplification and rationalization of the classification of contracted pelvis and was, he believed, destined to have a far-reaching influence on the teaching and practice of the future.

Professor MUNRO KERR said that Dr. Moloy had shown how, in pre-partum and intra-partum radiography a new method was to hand for the study of (*a*) the mechanism of labour; (*b*) the variations in movements which the head underwent when the pelvic formation differed from the female type. Obviously if wisely employed such information might be of great value in determining, before or during labour, the most suitable procedure to employ in a particular case. But the information furnished by this new method of examination must be used wisely and in conjunction with the other recognized methods of examination which had been employed up to the present.

It was satisfactory to learn that the exact observations which Dr. Moloy and his colleagues had carried out had not lessened the employment of "conservative methods" of delivery. The rates for forceps delivery and for "Cæsarean section" had not increased in the clinics in which these obstetricians had worked; on the contrary they had fallen. Members had just heard arguments in justification of "higher obstetrics" in which the subtleties of finesse were introduced into the practice of obstetrics, and surely these were stimulating.

There was, however, one point to which he thought Dr. Moloy should have referred, namely the influence exerted by the position of the back and shoulders of the child. While undoubtedly the formation of the pelvis affected position, flexion, extension, and rotation of the child's head, so also did the position of its back and shoulders. Radiographic examination must be utilized to correlate the influence which each and all of these factors exerted. Lastly he would stress the value of symphysiotomy and pubiotomy in the treatment of certain cases of malrotation and arrest of the head at the pelvic outlet.

Professor PRESTON MAXWELL said that in the cases with which he and his colleagues had to deal in Peiping, it was a matter of considerable difficulty to decide into what class pelves should be placed.

He questioned whether sufficient stress had been laid by Dr. Moloy and the workers to whom he had referred on the influence of rickets—even of mild degree—on the shape of these pelves and especially of those classified as "platypelloid".

Professor CHASSAR MOIR said he wondered whether Dr. Moloy thought that any useful purpose was served by continuing to teach students the meaning (or supposed meaning) of the terms "rickety", "flat", "simple flat", and "generally contracted" (justo-minor) pelvis. If the slate could be wiped clean and Dr. Moloy was empowered to rewrite this chapter of obstetrics, would he reintroduce these terms?

He understood that Dr. Moloy had recently been determining the circular area of the various planes of the pelvis and comparing these with the area of the cross-section of the fœtal head. He (Professor Moir) had also been working on this idea. By use of the Thoms's method of X-ray pelvimetry an outline of the brim of the pelvis, corrected for distortion and accurate in size, could be drawn in chart form. By lateral pelvimetry the length of the shortest diameter of the fœtal

head could also be obtained. A circle of this diameter was superimposed on the chart over the outline of the pelvic brim and a useful impression could then be obtained of the available space in the pelvis. Such a study referred to the brim only, but by clinical observation and by the help of lateral pelvimetry a useful knowledge could be obtained of the architecture of the lower portion of the pelvis. Dr. Moloy was able to make such observations more fully and accurately with his special " transparent " stereoscope, and this work was likely to become increasingly important. Meanwhile, the method just described gave information of considerable value which could not be easily obtained by any other simple non-stereoscopic examination.

Dr. CLARK NICHOLSON said that his criticisms of Dr. Moloy's paper were based on radiological measurements on more than 350 cases in a cottage hospital. He thought that Dr. Moloy had made too little mention of racial differences in the pelvis. The late Sir William Turner had pointed out that the Western European races were predominantly platypellic—i.e. had a pelvic index of less than 90, and his (Dr. Nicholson's) own series showed an average pelvic index of 88, suggesting that nearly 50% of the women of rural England had a pelvis of distinctly flattened type. On the other hand, the yellow and the negroid races were mesatipellic, and the more primitive races were dolichopellic, with a pelvic index of more than 95—the anthropoid type of Dr. Moloy. Did the bush people of Australia with this type of pelvis experience more than the usual proportion of difficulty in labour ? He (the speaker) thought that a classification of the pelvis which depended solely on appearances, and not on accurate measurements, was not truly scientific and could not be of permanent value in obstetrics. His figures tended to show that there was no close relationship between the shape of the pelvis and difficulty in labour.

Dr. MOLOY (in reply) : We have found that with care, considerable accuracy can be attained by clinical examination. At any rate distinctly abnormal cases can be recognized and referred for a complete roentgenologic examination. The terms *generally contracted pelvis, funnel pelvis,* and allied terms, inadequately describe the shape of the pelvis and hence should be replaced by a more accurate terminology. Dr. Nicholson has made use of the pelvic index and the three types described by Sir William Turner, in his roentgenologic studies. The lantern slides show clearly that pelvic shape at the inlet cannot be accurately determined by the ratio between the true conjugate and the widest transverse diameter. It is true that this ratio may show the long oval, the round, or the flat tendency, accurately enough for racial studies, but the important android or wedge-shaped type cannot be recognized by this method. For instance the pelvis with a platypellic index may be a true flat type or a classical android form. The well-formed flat pelvis is more efficient than the android with the same length to the true conjugate diameter. As a result, a description of the morphology of the pelvis, in conjunction with a record of the length of the cardinal pelvic diameters—as obtained by any method of roentgen-pelvimetry—represents essential steps in the study of the mechanism of labour.

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Section of the History of Medicine

President—A. P. CAWADIAS, O.B.E., M.D.

[*February* 2, 1938]

William Gilbert (1544-1603), Robert Fludd (1574-1637), and William Harvey (1578-1657), as Medical Exponents of Baconian Doctrines

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IT has bee often stated that the experimental method of modern science obtained its initial impulse from Francis Bacon (1561–1626); but how this impulse acted has not been explained, for Bacon's scientific sterility contrasts with the actual contributions to mathematical knowledge made by René Descartes (1596–1650) who, moreover, illustrated reflex action by experiment and wrote an elementary treatise of physiology.

Bacon attempted to complete a comprehensive survey of all extant knowledge; his system was planned on a most generous scale and with a vast design. Both as a philosopher and a patient he was intensely interested in natural science and "physick," yet only some of his tenets were relevant to biology and medicine. Certain authors, e.g. B. W. Richardson (1900), have stated that Bacon influenced medical progress in its most advanced departments; while others, like Minkowski (1934) consider that Bacon made a grandiose attempt to study Nature and subjugate it to the needs and use of mankind. Broad (1926) pointed out that Bacon, though a most pertinacious experimenter was also a very incompetent one, and that he failed to recognize several scientific advances that were taking place in his time while credulously accepting an inchoate mass of superstitious beliefs.

That Bacon was anticipated in the practical application of the experimental method by William Gilbert is known; that Harvey gave a brilliant demonstration of experimental biology is also universally admitted; less recognized is the application of experiment in the explanation of pathological processes made by Robert Fludd, the "Mystical Physician".

It is the purpose of this essay to indicate how Gilbert, Fludd, and Harvey practised what Bacon preached and propounded in his many writings, and that therefore they succeeded in converting Bacon's words into deeds.

THE PHYSICIAN WILLIAM GILBERT OF COLCHESTER

Gilbert was born in Colchester May 24, 1544; entered St. John's College, Cambridge, May 1588; B.A., 1560; Fellow, 1561; M.A., 1564; then travelled abroad and on his return to England was granted an M.D. degree at Cambridge in 1569. In 1573 Gilbert settled into practice in London, was elected a Fellow of the College of Physicians, and became its President in 1600. In that year his great work appeared: *De magnete, magnetecisque corporibus, et de magno magnete tellure; Physiologia nova, plurimus & argumentis, & experimentis demonstrata.* He died a bachelor in 1603 and left his books, globes, and instruments to the College, where they were destroyed in the great fire of 1666. Another work was published nearly fifty years after his death, edited by his brother: *De Mundo Nostro Sublunari, Philosophia Nova* (Amsterdam, 1651). This brother, also named William, seems to have been living 107 years after the birth of the senior in 1544! There is a note in the book stating that it is common in England to give brothers the same Christian name. Wood in his *Athenae Oxonienses* (1691) remarked that this William Gilbert was a Proctor of the Arches.

Fuller (1662) wrote:

"*Physicians.* I received the following intelligence from his near kinsman, Mr. William Gilbert of Brentnal—Ely in Suffolk. William Gilbert was born in Trinity Parish in Colchester, his father being a Counsellor of great esteem in his profession, who first removed his family thither from Clare in Suffolk, where they had resided in a Gentile Equipage for some Centuries of years. He had (saith my informer) the Clearness of Venice Glass without the brittleness thereof, soon ripe and long Lasting in his Perfections. He commenced Doctor in Physick, and was Physician to Queen Elizabeth, who stamped on him many Marks of her favour, besides an Annuall Pension to encourage his Studies. He addicted himself to Chemistrey, attaining to great exactness therein. One saith of him that he was Stoicall but not Cynicall, which I understand Reserv'd but no Morose, never married, purposedly to be more beneficial to his Brethren. Such was his Loyalty to the Queen, that as if unwilling to survive, he dyed in the same year with her 1603. His Stature was tall, Complexion Cheerful an Happiness not ordinary in so hard a Student and retired a Person. He lyeth buried in Trinity Church in Colchester, under a plain monument. Mahomets Tombe at Mecha is said strangely to hang up, attracted by some invisible Load-Stone, but the Memory of this Doctor will never fall to the ground, which his incomparable book *De magnete* will support to Eternity."

Little is known of the life of Gilbert, except that he spent many years and a great sum of money over his experiments with loadstones and that a learned group met at his rooms.

The properties of magnetic iron were known in classical antiquity. In the Middle Ages Roger Bacon (1210–1292) mentioned magnetic properties; he also praised Peregrinus of Picardy, whom he called *Dominus experimentorum.* Von Lippmann (1932), *op cit.*, p. 27, stated that a letter by Peter Peregrinus de Maricourt, dated 1269, described a rough form of compass. Mediterranean seafarers had made use of the magnetic needle in navigation in the thirteenth century, but the general properties of magnets were first consistently investigated by Gilbert.

The declination of the needle had been previously observed and described by Robert Norman in *The Newe Attractive, containing a short discourse of the Magnes or Lodestone and amongest other his vertues, of a new discovered secret and subtile propertie concerning the declinyng of the Needle.* (*London.* 1581.) Norman is, however, mentioned as a clever artificer in the first chapter of *De magnete* 1600, which is preceded by an address by Edward Wright (1558–1615), a mathematician and lecturer on navigation, who entered Caius College, Cambridge, in 1576, graduated M.A. 1584, and was a fellow 1587–96. Wright was the author of a book on the use of the compass

and other matters pertaining to navigation. In the preface there are those sentences which clearly indicate that Gilbert was fully aware of the merits of empiricism in natural science.

" To the Candid Reader, studious of magnetic philosophy. Since in the discovery of secret things and in the investigation of hidden causes, stronger reasons are obtained from sure experiments and demonstrated arguments than from probable conjectures and the opinion of philosophical speculators of the common sort etc. . . . To these men of early times and, as it were, first parents of philosophy, to Aristotle, Theophrastus, Ptolemaeus, Hippocrates, Galen, be due honour rendered ever, for from them has knowledge descended to those that have come after them ; but our age has discovered and brought to light very many things which they too, were they among the living, would cheerfully adopt. Wherefore we have no hesitation in setting forth in hypotheses that are provable, the things we have through long experience discovered. Farewell." [Translation by P. F. Mottelay, London, 1893.]

Here in a few sentences the modern trend of scientific research is described : namely the advancement of existing knowledge by experiment under conditions of control and comparison.

In the first chapter there is a reference to " the ingenious Fracastorio, a philosopher of no common stamp ". Gerolamo Fracastoro (1478–1553) was demonstrator of anatomy at Padua from 1501 to 1505, and in those years a young Polish medical student visited the " fair mother of the arts "—Nicholas Koppernik [Copernicus] (1478-1543), whose *De revolutionibus* propounded in 1543 the heliocentric system of the universe. Fracastoro, though best known for his poem on syphilis and his views on the " seminaria " of contagion, was also the author of a work entitled *Homocentrica. De causis criticorum dierum per ea quae in nobis sunt* (Venice, 1538) in which critical arguments were brought to bear against the Ptolemaic system of astronomy. On the last page of *De magnete* Gilbert wrote " Thus do the moderns, and in particular, Copernicus restorer of Astronomy, etc ". Gilbert accepted the heliocentric interpretation of the universe, which Bacon denied.

Fracastoro, Koppernik and Gilbert were all physicians, and their special interest in the mechanism of the universe can be attributed to the prevalence of medical astrology at the time. Paracelsus (1493–1541) in his coarse manner, had advised physicians " to cease poking their noses in excrements and to lift their eyes to the heavens ". The connexion between astrology and pathology is perhaps not so obscure ; in Gilbert's posthumous work the knowledge of the heavens is connected with meteorology and the influence of the seasons on epidemics must have often directed thought to the importance of the constellations.

The *De magnete* presents medical views which are advanced in relation to its time. Thus in Book I, Ch. XIV and XV entitled " Of other properties of the lodestone and its medicinal virtue " it is denied that magnetic iron in small doses could preserve youth ; that pulverized and buried in plaster it would draw out an arrow ; or that smeared with garlic the magnet lost its power. By contrast van Helmont (1577–1644) in *De magnetica vulnerum naturale et legitima curatione, etc.* (Paris 1621) stated that garlic was the magnet's proper hypnotic !

It is clear that Gilbert had made actual empirical observations. In Ch. XV the medicinal properties of iron were discussed ; then the preparation of iron powder was described and its astringent properties were mentioned, together with its use in chlorosis, ague, and enlarged spleen. In Book III Gilbert remarked that Galen was mistaken in teaching that antidotes drawing out the venom of snakes possessed the same power as the loadstone, for drugs did not act in that manner. Gilbert examined the assertion of Giambattista dalla Porta (1536–1615) that diamonds exerted a magnetic attraction, and, having tried out 75 diamonds, decided that this was not the case.

Gilbert's work was held in high esteem by Galileo (1564–1642) who repeated and controlled some of the magnetic experiments. Galileo's approval is significant,

because he was the first to correct Aristotle's assertions about the laws governing the fall of bodies and thus formulated the first accurate laws relative to gravity.

The learned Venetian theologian, Paolo Sarpi (1552–1623) whose scientific interests were most varied, also praised Gilbert's book and compared him to François Viete (1540–1603) an outstanding mathematician.

The names of Gilbert and Harvey, together with Descartes, were admiringly mentioned by that picturesque personality, Sir Kenelm Digby (1603–1665) in *Two Treatises, in one of which the Nature of Bodies etc.* (Paris 1664.) In Ch. XXVI, p. 239, he wrote :

" But referring this doctrine [the circulation] who has both invented and perfected it . . . Doctor Gilbert . . . by means of whom and of Doctor Harvey our nation may claim even in this later age as deserved a crown for solid philosophical learning."

Digby's scientific achievements are nugatory, but he can be considered to reflect contemporary opinion in relation to the merit of Gilbert's investigations, which Bacon criticized by saying that Gilbert had attempted to build a ship out of material sufficient to make a thowl-pin !

Hale-White in the Harveian Oration of 1927, after carefully examining various relative documents, suggested that Gilbert by his example helped to direct Harvey's thoughts by teaching him the right way to investigate Nature's problems by experiment and induction.

The results of the experiments described in *De magnete* were not appreciably increased till the astronomer John Michell (1724–1797) published in 1750 his *Treatise of Artificial Magnets*. Gilbert's significance in the history of the experimental method was recognized by John Aikin (1747–1822) who in *Biographical Memoirs of Medicine in Great Britain* (1780) wrote :

" The capital work of Dr. Gilbert was first published at London and has been reprinted in Germany. This is not only the earliest complete system of magnetism, but also one of the first specimens of a philosophical system built upon experiments after the manner so much insisted on afterwards by the great Lord Bacon."

Similar pronouncements will be found by several other authors, and notably in the works of Silvanus P. Thompson. Thus Gilbert's example appears more productive of lasting results than Bacon's precept.

The rôle of William Gilbert in the history of science is certainly remarkable, whatever the criterion employed ; that of a contributor to pure knowledge or science ; or because of the technical achievements connected with the working of the compass, and the later developments of electro-magnetism ; or as one of the earliest exponents of the Experimental Method.

The Mystical Physician Robert Fludd

Born in 1574 at Milgate Manor, near Bearsted, Kent, of a family of Welsh origin ; entered St. John's College, Oxford, 1591, graduated M.A., 1598, then travelled six years on the Continent, visiting France, Spain, Italy, Germany. Returning to England he became a member of Christ Church, Oxford, and on May 16, 1605, received the degree of M.B. and M.D. Early in 1606 he was twice examined by the College of Physicians and eventually qualified to practise medicine. Later he was examined as a candidate for the Fellowship of the College, but difficulties again arose and Fludd " *tam insolenter se gessit* " that he was admonished on March 21, 1608 ; however, on September 20, 1609, he was elected a Fellow. He then practised in London as a physician and in due time became Censor of the College in 1618, 1627, 1633–4. He employed his own apothecary and amanuensis ; to the latter he dictated

at all hours his voluminous treatises *de omne re scibili et quibusdam aliis*. He was a clever mechanician and is reputed to have constructed a wooden bull that bellowed, an automatic dragon, and a self-playing lyre. He died a bachelor, September 8, 1637, in his house in Coleman Street, London, and was buried in Bearsted Church.

Fuller, *op. cit.*, p. 71, wrote :

" Robert Floid, who by himself is latined *Robertus de Fluctibus*, was born in this County, and that of a Knightly Family, as I am informed bred (as I take it) in Oxford, and beyond the Seas. A deep Philosopher, and a great Physician, who at last fixed his habitation in Fanchurch-Street, London. He was of the Order of the Rosa-Crucians and I must confess myself ignorant of the first Founder and Sanctions thereof, perchance none know it, but those that are of it. Sure I am that a Rose is the sweetest of Flowers, and a Cross accounted the sacredest of forms or figures, so that much of eminence must be imported in their composition.

" His Books written in Latine are great, many and mystical. The last some impute to his Charity clouding his high matter with dark language, lest otherwise the lustre thereof should dazzle the understanding of the reader. The same phrases he used to his patients : and, seeing conceit is very contributive to the well working of physic, their fancy or faith natural, was much advanced by his elevated expressions.

" His books are for the English to sleight or admire, for French or Forraigners to understand and use ; not that I account them more judicious than our own Countrymen, but more enquiring into such difficulties."

We may turn therefore to consider what the French and Foreigners thought of Fludd. Taking first the dictionary makers, Jean-Eugène Dezeimeris (1799-1852) : *Dictionnaire historique de la médecine* (Paris, 1814), we find :

" or dans cette science [médecine], nous ne pensons pas qu'il soit possible de faire quelque-chose de plus absurde que les oeuvres de Fludd. Nous regarderons comme fort mal employé l'espace que nous donnerions à l'analyse de pareils ouvrages etc."

Other French dictionaries, such as Jourdan, reveal variations on the same theme, but in the *Biographisches Lexikon der Hervorragende Aerzte* (Vienna, 1885) it is said :

" Fludd, Robert (De Fluctibus) Theosoph, Mystiker, Rosenkreuzer, Dr. med. warscheinlich zu Oxford, später in London auch aerztlich thätig und 1637 gestorben, war ein langweiliger Vielschreiber, etc."

A further example can be quoted from the *Enciclopedia Italiana* which has just been completed.

" Come filosofo il Fludd subì fortemente l'influsso di Niccolò de Cusa e di Paracelso, insieme a quello del neo-platonismo che affermandosi nella cultura filosofica inglese, preannunciava la scuola di Cambridge. Il suo sistema è un emanatismo che vede in Dio la cusaniana *coincidentia emanatorum*, unico germe dell' infinite diversità delle cose : tendendo quasi, con ciò, a considerarlo identico al Nulla, in forza alla sua indeterminatezza."

If we turn to the *Enciclopedia universal ilustrada europeo-americana* (Barcelona, 1924) we read under " Fludd " :

" Uno de los hombres màs eruditos de su tiempo. Adversario de los peripateticos y en general de toda filosofia pagana, importò à Inglaterra la filosofia natural y la teosofia de Paracelso y de Cornelio Agripa. En sus obras se refleja un panteismo materialista presentado en formulas misticas."

Nevertheless it can be said that Fludd was the first practising physician who tried to explain pathology in terms of demonstrative experiments, the descriptions of which are scattered through the pages of his voluminous writings.

In the two handsome volumes in the Cambridge University Library entitled " *Utriusque cosmi majoris scilicet et minoris metaphysica physica atque technica.*

Historia in duo volumina secundum cosmi differentiam divisam " (Oppenheim, 1617). In *Tract. II, Pars VII, Lib. III* (p. 471), there is an illustration of a candle burning in a flask inverted over water ; it is said that water is attracted into the flask in proportion of the air consumed, for air nourishes fire. The deduction in *Regula* VI is that if air is evacuated in a closed space or consumed, the space must be filled by a new body. This is one of the earliest attempts to solve a problem of the nature of air. For this reason, the paragraph will be quoted in full : (p. 472).

> " In secunda demonstratione candela in fundo vasis alicujus aqua repleti affigitur, cujus flamma per orificium phialæ ingrediens depresso ejus orificio ad angulos rectos cum candela in vasis aqua sursum attrahet tantam aquæ proportionem, quantam aeris in fiala inclusi consumpserit : Aer enim nutrit ignem, & nutriendo consumitur."

The candle burning over water is illustrated also on p. 457 of Fludd's *Integrum Morborum Mysterium sive Medicinae Catholicae, Tomus I, Lib. IV, Membr. IV. Demonstratio* on p. 456 and *Applicatio ad hominem* on p. 457, where it is employed to explain the origin of " phrenzies ". It may be reflected that the real cause of some mental diseases is still obscure, even after Fludd's explanation !

Then on p. 424 and p. 432 we find a boiling pot illustrated with the steam condensing on the lid, which is suspended by a hook. This serves to demonstrate the reason of the running nose and weeping eyes in coryza and rheum ; the steam produced in the overheated liver and bowels condenses in the skull-cap and then drops from the nostrils. I consider this a very plausible explanation, but a similar description occurs in one of the writings of Cesalpino (1603). Haeser (1881) stated that Fludd was the first to measure the heat of the blood with a thermometer ; this must allude to some test with the baro-thermometer or open thermometer, which played a great role in Fludd's pathology. Fludd did not claim to have discovered the instrument, which was known to Giovanni Sagredo in 1613 and in all probability was first made by Galileo ; moreover Santorio Santorio (1561–1636) mentioned its clinical use. The involved early history of the clinical thermometer is not easy to unravel.

It can be added that Fludd was the first, in 1631, to express approval in print of Harvey's doctrine of the circulation of the blood. Moreover Harvey sent *De motu cordis* to be printed by William Fitzer in Frankfurt, who was Fludd's printer ; Fludd stated bluntly that German printers offered better terms than those at home.

Concluding, it can be said that Fludd was among the first who tried to explain pathology by means of experimental models or tests. Even though he drowned his results by much irrelevant speculation, the method initiated was based on correct principles.

William Harvey of Folkestone

Born April 1, 1578, in Folkestone, Harvey, after instruction at the Grammar School, Canterbury, was admitted to Caius College, Cambridge, in 1593 ; in 1598 he went to Italy, matriculated at Padua in 1600, becoming Doctor of Medicine in 1602. He then returned to England and settled in practice in London. Harvey was appointed Lumleian lecturer to the College of Physicians in 1616 and appears then to have asserted the complete circulation of all the blood ; the notes of these anatomy lectures were reproduced in autotype in 1886.

The *Prelectiones* reveal the inner working of Harvey's mind in a manner reminiscent of Pepy's diary. In these notes Dr. Gilbert, Dr. Fludd, Cesalpino are named, and allusion is made to a " Cambridge scholer " who was asphyxiated ; it is strange that though Harvey frequently referred to Padua, this is the only time Cambridge is recalled.

An example of the peculiar style is the following :

f. 73. Aquapendens dixit scabrosum cor.
WH. ego flaccidum valde et pallidus
Audivi corde vulneratus ad tempus vixisse et alium occidisse
Exempto corde frogg scipp eele crawle dogg Ambulat

Harvey was an ardent Aristotelian and referred to Aristotle's statement that the heart consisted of three cavities.

f. 74. Ventriculi duo dexter et sinister
WH Admiror Aristotelem cum iij ita exacte describit
Autor tam dilligens et fidelis nec salvar

It is known from John Aubrey (1626-97) that Harvey had been physician to Bacon, though the exact date does not appear to be ascertainable. If after 1616, then it is possible that something about the circulation may have been said between doctor and patient, but any allusions to the flow of the blood in the writings of Bacon are vague and uncertain.

Since Bacon died in 1626, two years before the appearance in print of *De motu cordis* and the first approving mention of the circulation was that of Fludd in 1631, it seems probable that Harvey's lectures from 1616 onwards were either not understood or neglected as propounding unproven theories. This I have attempted to make clear elsewhere (" Annals of Science 1938 "), but it may be mentioned that the neglect of Harvey's views by Bacon and his contemporaries, may be taken to confirm that the assertions of Realdo Colombo and of Andrea Cesalpino (who had studied medicine at Pisa in Colombo's time) were not commonly understood to relate to a complete circuit of the whole blood, but only to a possible passage of a small quantity through the lungs ; this is indeed the recorded opinion of anatomists at the time. Another reference is by Izquierdo (1937). The first mention of the priority of Cesalpino was by Giovanni Nardi, a personal friend and correspondent of Harvey, in *Noctes geniales* (Bologna, 1655), therefore already during Harvey's lifetime.

Reverting to the well-known remark of Aubrey (1898, vol. 1, 299)

" (Harvey) had been physitian to the Lord Chancellor Bacon, whom he esteemed much for his witt and style, but would not allow to be a great philosopher. ' He writes philosophy like a Lord Chancellor ', he said to me, speaking in derision ; ' I have cured him '."

Anyone who reads the elaborate plans for the House of Solomon in the *New Atlantis* must admit that there was truth in Harvey's alleged saying. Bacon did indeed write with the solemnity of a Lord Chancellor and, it may be added, with the same aloofness from everyday occurrences.

In view of Harvey's observations on hatching eggs, it is interesting to note that Bacon wrote :

" If we could observe the hatching of eggs, we would easily see the process of animation and organization and what parts are formed of the yolk and what of the white of the egg."

The trend of thought of Bacon and Harvey reveals some similarity in relation to several subjects which need not have been fortuitous. Some sentences in Harvey's works might have been written by Bacon, e.g. in the Introduction to the *De generatione* where it is said :

" Without the due admonition of the senses, without frequent observation and reiterated experiments, our minds go astray after phantoms and appearances."

The resemblance to the " idols " of Bacon may mean that Harvey had read and noted the remarks about the Idols of the theatre.

When the subject is examined as a whole, it seems evident that in all probability Harvey was more influenced by what he learnt at Padua or read in the *De re anatomica* of Realdo Colombo or obtained in conversation with Gilbert or even Fludd, than what appeared in the writings of Bacon, which Harvey seems to have considered rather abstruse, as indeed they were.

Francis Bacon, Baron Verulam, Viscount St. Albans

The life of Bacon is recorded in his biographies, and among his many writings the following have been found particularly relevant to biological and medical subjects :—

The two Books of Proficience and Advancement of Learning, Divine and Humane (London, 1605). *Novum Organum Scientiarum* (London, 1620). (This was consulted, for the purpose of this paper, in the text of Bacon's *Novum Organum. Edited with introduction, notes, &c., by* Thomas Fowler, Oxford, 1889.) *Historia vitae et mortis*, 1623. *Sylva sylvarum. New Atlantis.* (London, 1627.)

In these works Bacon, with a wonderful command of language and considerable prolixity, pleaded for the investigation of first principles and the examination of natural phenomena by experiment. Though the general trend of the argument is quite clear, the meaning of single statements is less so. As an example there is the first aphorism in *Novum Organum :*

> " Homo naturae minister et interpres, tantum facit et intelligit quantum de naturae ordine, re vel mente observaverit : nec amplius scit aut potest ".

This has been variously understood and translated ; but taking the words in their literal meaning one may say : " Man, minister and interpreter of Nature, makes and understands of the order of Nature, the things and the reason thereof, as much as he has been able to observe ; more he cannot know or do." To-day this may appear to be a platitude ; but in Bacon's time the deeper inference was revolutionary ; for it meant that it was possible to ascertain the laws governing the world around us only by the use of our senses.

It cannot be claimed that had Bacon not lived, scientific thought would not have progressed along experimental lines. Gilbert had already made a definite beginning and he was soon followed by Harvey in relation to the demonstration of the circulation of the blood ; moreover Fludd, in his own mystical way, tried to explain some problems in pathology by experiments. It is significant that scornful reference was made by Bacon to the opinions of these three.

In the well-known pages of the *Novum Organum*, Bacon discussed at length the harm caused to right thinking by the Idols of the tribe, the Idols of the den, the Idols of the market-place, and the Idols of the theatre. Though the designation of idol as a false god fits in with the sense of the text, yet it appears that the word is derived from the Greek εἰδωλα meaning phantom or spectre. The Idols of the theatre were so designated because they succeeded each other like plays on a stage ; they arose from three false systems of philosophy ; in the words of Bacon these were, first of all, the Rational or Sophistic, then the Empiric, and lastly the Superstitious.

The first dealt little with experience and much with speculation and the type was Aristotle, who corrupted natural philosophy by his logic. Harvey was an ardent admirer of the Stagirite, whose primacy of the heart was the basis of much of the reasoning both in the *Prelectiones* 1616 and in *De motu cordis* 1628.

The next almost exclusively concerned with experiments with such a narrow compass that they scarcely elucidated great problems. These were the Alkemists, among whom Bacon reckoned Gilbert !

Thirdly were the superstitious doctrines that corrupted philosophy by an admixture of superstition and philosophy. Though Bacon did not mention Fludd by name,

anyone reading the text will admit that the designation would be apt; indeed Fowler said that the allusion was intended for Fludd.

Allbutt (1921) noticed the resemblance between some of the opinions of Bernard Palissy (d. 1589) and those of Bacon, who was in Paris as a youth, when Palissy was lecturing on natural science. In Bacon's writings there are definite echoes of Palissy's doctrines and here a frequent contradiction in Bacon's writings may be mentioned; his much-quoted saying:

> "Men are inclined to turn aside from their experiments for some practical application of them; like Atalanta, they go aside to pick up the golden apples and let victory escape them; they should seek for experiments of light, not for experiments of fruit."

The whole trend of Bacon's striving was for "experiments of fruit"; for, particularly in medicine, there can be no pure theoretical knowledge; every atom has for purpose treatment or prevention of disease and the preservation of health and life.

It is not possible to do Bacon justice in a few paragraphs, but it may be said without unreason, that with the fullest and most unstinted admiration for the grandeur of his plans for the reformation of knowledge, the advancement of science and the harnessing of Nature to the needs of man, Bacon fell lamentably short when attempting to put his theories to the test. His aim was too high to be attained by the efforts of a single man.

It is extremely difficult—perhaps impossible—to make a clear-cut distinction between wisdom, belief, and superstition, particularly at the time of Gilbert and Bacon; but if the works of Gilbert, Harvey, and Bacon are compared, it is noticeable that the first two are singularly free from baseless credulity, whilst Bacon in *Sylva sylvarum* and other writings accepted numerous instances of erroneous belief.

Bacon's collection of facts and records of experimental observations in *Sylva sylvarum* are most unfortunate; they reveal to the fullest extent the feet of clay and disclose the limitations of thought without action. Evidently Bacon was not only unable to build the palace he had planned, but would be incapable even of tenanting it. This notwithstanding Bacon's philosophical system proved a source of inspiration for following generations, even though biology (and consequently medicine) followed the path traced by the work of Gilbert, Harvey and—it may be added, with reservations—Fludd.

It will be objected that I am not justified in mentioning Gilbert, Harvey, and Fludd as exponents of the Baconian system, because one produced his work before the appearance of Bacon's first pronouncements and the other two took no notice of his work; moreover, because Bacon poured scorn on all three. Still, the Baconian system is something definite and concrete, being recorded in numerous writings; its coherent tenets can be stated on a single sheet of paper. These tenets, I deem, Gilbert put into practice in the investigation of magnetism, Harvey in demonstrating the function of the heart and to a lesser extent in relation to the problems of generation and Fludd applied them to explain, however erroneously, many problems in pathology, therapeutics, and medicine in general. The contention is that Bacon's philosophy would have remained sterile had it not been tended, nourished, and brought to fruit by others.

Experimental Science in Bacon's Time

The "New Learning" of Bacon's time or study of natural laws by means of small-scale tests under prepared conditions, did not find a welcome acceptance in the Universities of Great Britain, France, Italy, Spain, or Germany, though in Scandinavian countries (Denmark, Sweden) there were single exceptions. Examples of these experimental methods would be Gilbert's "terrella" or small-scale globe; also Harvey's examination of the excised heart of snakes, eels, or shrimps; or Fludd's

open thermometer, however inaccurate may have been the conclusions he obtained from its behaviour in the heat or cold. It must be for this reason that experiments were made in the short-lived "Accademia dei Segreti" of Giambattista dalla Porta of 1560; it has been seen that a learned society met in Gilbert's rooms. The Accademia dei Lincei of 1603 sported the symbolical device of a lynx rending with its claws a Cerberus. In Germany the *Academia naturae curifossorum* was founded in Schweinfurt in 1652. Then the "Accademia del Cimento" (the Academy of Test) was established in Florence in 1657 with the definite purpose of obtaining knowledge by experiment. Though it can be admitted that Bacon inspired the formation of the Royal Society, yet there were several examples on which he might model the "House of Solomon" described in the *New Atlantis*. The Royal Society, in the first century of its existence, particularly through the investigations of Malpighi, Lower, Wren, Hooke, Boyle, and the prolonged observations of van Leeuwenhoek, debated several matters of general biological and medical interest, such as intravenous injections, blood transfusion, respiration, the action of poison and drugs, the microscopy of living tissues. The remarkable advances in the knowledge of pathogenic bacteria that were originally based on the purely biological investigation of the problem of "spontaneous" generation need only be recalled to explain that Bacon, through his approval of experimental study, did encourage those who were attempting to scale the walls of the citadel of medicine.

The Experimental Method and the Evolution of Modern Medicine

A study of the lives and works of Gilbert, Harvey, and Fludd, shows that though each, in his sphere, investigated magnetic, biological, or medical problems by means of experimental methods, Bacon did not acknowledge that they were employing the system he had propounded and was exceedingly critical of their principles. Correspondingly, Harvey and Fludd appeared quite unconscious of having been inspired in the very least by Bacon's tenets. It may be recalled that Thomas Hobbes (1588–1679), who had been Bacon's amanuensis some time between 1621–6, did not mention his system in the text of *Elementorum philosophiae* (London, 1655); in the preface of which there is a reference to Harvey, to the effect that he was the only one, whom Hobbes knew, who had overcome envy and seen the system he propounded acknowledged during his lifetime. Neither is Bacon named in Hobbes' *Decameron physiologicum or Ten Dialogues of Natural Philosophy* (London, 1678).

There must have been personal reasons for this neglect, but from the historical point of view, the omission need not preclude an attempt to follow the thread through the labyrinth. It can be objected that Bacon was the best judge of the principles he evolved in his philosophy; still, later generations are better acquainted with the development of science and medicine after his time, and can decide from a greater volume of evidence.

For this purpose the course followed by medicine since Bacon's age can be briefly stated. Medicine originated from a desire to cure disease and preserve life, which has been evident in the human race from time immemorial; therefore the history of medicine can note the continuity of this effort and measure its results by the extent to which they have been crowned by success.

The examination of recorded evidence shows that during two centuries after Gilbert, Bacon, Harvey, knowledge in natural sciences, such as zoology, botany, mineralogy, then chemistry and astronomy, increased greatly in many countries, while anatomy, physiology, medical diagnosis became accurate. There was relatively little progress in therapeutics, prevention of epidemics or knowledge of ætiological causation, though some in diagnosis and prognostication. The medical reaction to the scientific advances consisted in the appearance of strange and wonderful systems,

known as Iatrophysics, Iatrochemistry, Brownism, Mesmerism, Homœopathy, which varied greatly in their effectiveness and the influence exerted on progress, for some of them were distinctly retrograde in outlook.

If the advances during these two centures in astronomy, chemistry, physics, biology are considered, it may appear as if science rushed on and medicine stuck fast. It would however seem more accurate to say that scientific knowledge hurried on and dragged medicine along with it till it became applied science, instead of individualized speculative therapeutics, of the type of which Fludd presented a shining example. None the less, it may be mentioned that astronomers such as Copernicus, Galileo, chemists like Cullen and Black, or physicists, e.g. von Helmholtz, if not physicians, yet had a medical education. This has been very nicely expressed in an essay by Garrison (1933), with the title : " What Science owes to Medicine."

The Development of Contemporary Medicine

The technical applications of scientific knowledge have brought about some of the revolutionary changes which Bacon foresaw in the social order of humanity all over the world ; in relation to medicine the change has been equally intense and profound.

The improvement following the increased anatomical knowledge obtained through Vesalius was enhanced by the application of experimental methods by Gilbert, Fludd, Santorio, Harvey, Malpighi, Lower, which ultimately produced accuracy in diagnosis and treatment. The systems of speculative philosophers, like Francis Bacon or René Descartes, appear to have been evolved after the initial impulse given by experimenters like Galileo or Gilbert so that it may be said with reason : " *Im Anfang war die Tat* " (In the Beginning was the Deed).

Therefore, the influence of Bacon on the development of medicine cannot be considered to have been direct, in the sense that Harvey's work and writings proved a dynamic incentive to further investigations by the new methods he had demonstrated. Bacon's inspiration made itself noticeable by advising the recognition of the laws governing natural phenomena and the critical investigation of fundamental axioms ; together with the encouragement of all attempts to obtain technical achievements, many of which he foresaw in his writings ; all these matters eventually succeeded in furthering medical progress.

Then Bacon instigated the formation of the Royal Society, which debated and furthered scientific subjects away from the hostile atmosphere of the Universities, which, on the whole, were opposed to the new learning ; in this manner he certainly furthered the progress of natural sciences and consequently medicine.

Bacon failed to recognize the correctness of the Copernican doctrine or the lasting importance of Gilbert's work and, in contrast, uncritically accepted many superstitious beliefs ; moreover he was a most enthusiastic and futile experimenter—thus proving how dependent experimentation was (and still is) on rational preparation or reasoning. Nevertheless, one may plead that he should not be judged by what we know of his life or too severely criticized for the evident inaccuracy of much of what he wrote ; but rather we should remember how, in the course of a travailed existence, he consistently propounded the acquisition of living knowledge on a universal scale and recognized the virtues of an adaptation of science to the immediate necessities of mankind, particularly in relation to medicine.

As to Gilbert, Harvey, Fludd, the first two were in reality the principal instigators of subsequent advances in physics and biology, by the demonstration of methods which were then so brilliantly conjoined with those of chemical research by Boyle and Lower and those who followed them in the investigation of the problems arising from a better knowledge of respiration. From the historical standpoint therefore, though the roots of natural philosophy and modern medicine were closely set, a separation

between two trunks soon occurred ; and flowers and fruit appeared on the branches of biology and other sciences which were then gathered and applied to medical uses.

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Section of Neurology

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Some Observations on Cerebral Injuries

PRESIDENT'S ADDRESS

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THERE is considerable discrepancy between the pathology of cerebral injury as described in most textbooks and monographs, and that of spinal injury, so fully examined during the War by Gordon Holmes, Roussy and Lhermitte and others. The lesions in the injured brain appear to be predominantly vascular. In injuries of the cord also capillary hæmorrhages in the grey matter and very occasionally true hæmatomyelia may be found, but the most constant lesions and those to which the symptoms appear to be due, are in the nerve-fibres. These lesions usually extend up and down the cord for some distance from the level of greatest injury. For example, in the not uncommon momentary dislocation of the cervical spine associated with rupture of an intervertebral disc, changes in the white matter can be found in fatal cases several segments above and below that corresponding to the vertebral lesion. Further, there is clinical evidence in many such cases that the level of the lesion in the cord may rise several segments, or that the degree of paraplegia may increase and on post-mortem examination this is found to be associated, not with hæmorrhage, but with a spread of œdema within the cord.

The pathology of spinal contusion is limited and easily elucidated. The lesions appear to result directly from stretching or sudden acute bending of, or pressure on, the nerve-fibres, that is to a mechanical or physical process. The theory that they are caused by a momentary ischæmia due to compression of blood-vessels will not stand experimental testing. Further, their relationship to symptoms is not difficult to trace. They therefore give us a simplified instance of the effects of sudden deformations on nervous tissue.

These observations on spinal concussion naturally raise the question whether similar lesions of nerve-fibres occur in severe concussion of the brain ; and if they do so what part they play in the production of symptoms both in the early and the late stages. But most articles dealing with the pathology of cerebral injury say nothing about such lesions. On the other hand they focus attention almost entirely on the vascular changes, especially capillary or larger hæmorrhages and dilatation of vessels. Neuroglial scarring is only mentioned in relation to the more severe lacerations of the brain, and little or no mention is made of lesions of the white matter. There are two alternative explanations of this discrepancy. Either the physical conditions within the skull are so different from those within the spinal cord that the effects of deformations on the enclosed nervous tissue are quite dissimilar, or there has been, if not an error, at least a defect of observation. In favour of the latter possibility is the size of the brain, and the difficulty of determining in most cases which parts have been most injured. And the much greater frequency of hæmorrhage after cerebral injury not only distracts attention from the finer effects, but makes them more difficult to find and to assess.

Undoubtedly also there are great differences in the physical conditions associated with sudden cranial and spinal deformations, both as regards the bones, the blood-vessels and meninges and the nervous tissue involved, and to these the more obvious differences in the pathology of cerebral and spinal lesions are no doubt due. The question is, however, still open to what extent direct mechanical effects on the

nerve-cells and the sudden stretching, bending, or compression, of nerve-fibres is the basis of the symptoms of concussion of the brain.

This question, of course, is not a new one. It is in fact the basis of the old theory that the symptoms of concussion or commotion of the brain were due to a molecular disturbance in the nerve cell and fibre. Obersteiner, as long ago as 1900, considered that it was possible to substitute for the term molecular disturbance well-defined degenerative pictures. Recent work, while doing much to confirm this view, has also discredited certain of the observations on which it was founded.

Pathological Anatomy of the Injured Brain

The gross appearances of the brain of a patient dying soon after a severe injury to the head are so well known as scarcely to call for description. Bruising of the cortex, especially where the convolutions come to the surface, and wedge-shaped areas sometimes passing from these cortical bruises into the white matter are seen most often both directly under the area of the skull which received the blow and on the opposite surface in the area of contrecoup. Most often the undersurface of the frontal lobes, and the temporal and occipital poles, are bruised in this manner. Spreading from these areas there is a variable amount of subarachnoid bleeding and of

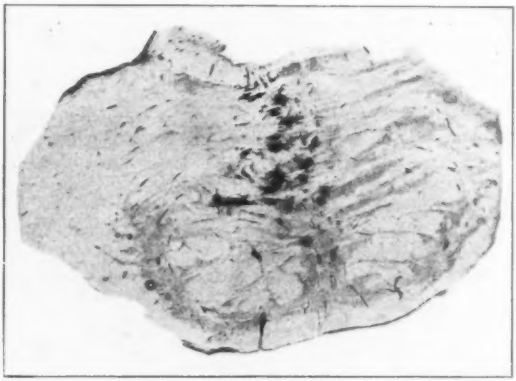

Fig. 1.—Transverse section of pons from a case of head injury with fracture of the skull, dying less than thirty minutes after the accident. (Pickworth's method for blood.) Showing multiple small hæmorrhages along the line of the median raphe.

hæmorrhage into the white matter. In addition small hæmorrhagic areas may be seen more diffusely in the white matter of the brain under the walls of the ventricles and in the pons or elsewhere in the brain-stem (fig. 1). They are perhaps more common round the aqueduct of Sylvius than elsewhere, but quite often lie more deeply in the tegmentum. As is well known, the contrecoup hæmorrhage may be much more severe than that under the part of the skull which received the blow. I have seen, for example, a gross frontal hæmorrhage as the chief, if not the only, cerebral lesion in a man who fell in a fit on the back of his head and cracked the occipital bone in the sagittal plane. But sometimes the damage caused by contrecoup is much less than that at the site of injury. This is usually the case when the blow is caused by an implement with a small surface, which pierces or shatters the skull locally.

There are, in addition, cases in which no gross hæmorrhage can be seen in the brain, which looks macroscopically normal. These cases present the greatest difficulty to the pathologist, and raise again the question whether the distinction between *concussion* and *contusion* of the brain is not too artificial to be retained. *Contusion* suggests, if it does not actually postulate, hæmorrhagic bruising of some part of the

brain, a condition which can be easily seen at the time in fatal cases, and the results of which persist and are evident enough many years after the accident. But these cortical bruises have no very close bearing either on the symptomatology or the severity of the case, although they are most common when the injury has been severe. As used at the present time the terms " concussion " and " contusion " are purely clinical terms, indicating varying degrees of severity of symptoms, and in the present state of our knowledge of the pathology of brain injury, should surely be replaced by terms which do not suggest a difference in pathological effects.

I do not intend to say anything about extradural or subdural hæmorrhage except that subdural hæmatomas may be associated with hæmorrhages into the white matter near the vertex of the brain. In one case, which came under my observation recently, the freshness of the blood in this intracerebral hæmorrhage suggested that it did not occur at the time of the injury but was related in some way to the operation for removal of the clot.

Œdema.—Many surgeons refer to the brain, as seen during decompressive operations, as pale and swollen. This suggests an œdema of the brain, and Freeman has described this as being either local or general. I believe that local œdema is common, but I have not found much evidence for general œdema of the brain. No doubt our methods for assessing this condition are inadequate, and it can well be imagined that a degree of general œdema which was too slight to produce any histological evidence of its presence might cause death from increased intracranial pressure. Against this assumption is the fact that apart from gross hæmorrhage the increase of intracranial pressure which follows even fairly severe cerebral injury is not great. Ritchie Russell found abnormal increase of cerebrospinal fluid pressure (above 200 mm.) only 30 times out of 49 lumbar punctures, and on only nine occasions was the pressure above 300 mm., and he noted that the pressure bore little relation to the degree of coma. This has recently been confirmed by Zierold, who did not find increase of intracranial pressure a common cause of death or of prolonged unconsciousness in his cases. We shall, therefore, be wise to withhold judgment as to whether general brain swelling may follow cerebral injury.

In cases in which the patients survive the injury and die months or years later, the most characteristic evidence of the head injury consists in the presence of cortical defects, affecting only the summits of the convolutions, and associated with a certain degree of demyelination and neuroglial scarring in the underlying white matter (Neuburger and v. Braunmühl). They are most often seen on the tips of the occipital or temporal lobes, or on the undersurface of the frontal lobes, and may be of quite small size (figs. 2 and 3).

The presence of old blood pigment in the margins of the defect and in the overlying meninges indicates that they result from the absorption of bruised areas of cortex. In most cases the cortex on the edge of the crater is perfectly healthy, but sometimes " calcified " nerve-cells may be seen there.

The question of *traumatic cysts* in the white matter is still undecided. I have seen several cysts lined with a layer of vascular granulation tissue which appear, from the history, to be related to a cerebral injury, and they might well be the sequelæ of a hæmorrhage into the white matter, such as is commonly seen in recent cases.

Where the skull has been fractured there is more extensive loss of cortical tissue and of the white matter underlying it. In addition there may be much more extensive demyelination and gliosis than the cortical loss would warrant. This gliosis, surrounding an injured area of brain for some distance, was pointed out by Ritchie Russell, but he did not, I think, arrive at its true explanation. A few years ago Dr. Milton L. Miller and I had the opportunity of examining the brains from two cases of severe injury to the frontal region, associated with fracture of the bone. In both cases unconsciousness had been prolonged for several days. One patient died in a fit seventeen years after a bullet wound of the forehead; the other died five years after a motor-cycle collision from pneumococcal meningitis supervening on cerebrospinal

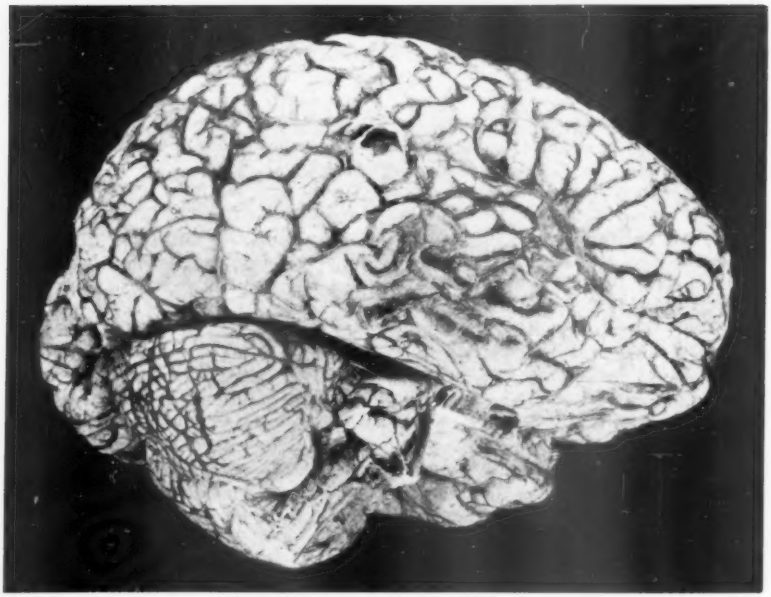

FIG. 2.—Brain from a case of head injury with fracture of the skull eleven years before death. An area of superficial cortical erosion is present near the pole of the right temporal lobe.

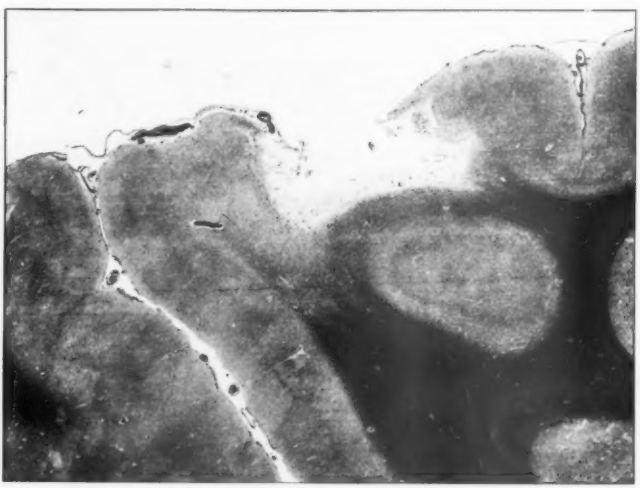

FIG. 3.—Occipital cortex from a case of head injury nine years before death. The loss of tissue is confined to the cortex on the summit of the convolution. (Mallory's phosphotungstic acid hæmatoxylin.)

rhinorrhœa. We were struck in both these cases by the extreme demyelination which was found in both frontal lobes, not only on the side which was directly damaged. This demyelination resembled that seen in Schilder's disease in sparing the subcortical U fibres, but was not nearly so obvious to the naked eye as that of Schilder's disease. It consisted in a general thinning of the myelin sheaths rather than a complete loss in most areas. As a rule areas of the brain which were directly bruised were completely demyelinated, but in less severe degrees the individual myelin sheaths were thin and beaded and stained poorly with hæmatoxylin. The associated gliosis took the form of a diffuse feltwork in which, in the more recent case, the neuroglial astrocytes were still greatly swollen.

Later observations have indicated that this type of demyelination occurs whenever there is severe œdema of the brain. It is seen, for example, in the œdema round cerebral tumours and hæmorrhages. And it seems likely that the demyelination which we found under the injured area of the skull was, at least to a large extent, caused by œdema.

I agree with Stevenson that it is logical to find in this demyelination and loss of tissue, rather than in the associated gliosis, the explanation for the wandering of the ventricles to the side of the lesion which has been shown by Foerster and Penfield and others to follow severe injuries to the brain, especially in cases with fracture of the skull. Obviously the loss of myelin will result in the course of years in shrinkage of that part of the brain, a shrinkage which has to be compensated for either by accumulation of fluid over the cortex or by local enlargement of the ventricle. Actually appearances indicating either or both of these may be seen in encephalograms. No doubt the contraction of the neuroglial scar aids this shrinkage but it is not, I think, the primary factor.

Seeing that demyelination in the brain is not, so far as we know, repaired, a poverty of myelin of this kind, when found in localized areas, may well indicate the sites of the œdema which follows head injury. Two cases of old head injury illustrate this point.

Case I.—A man aged 55 died of amyotrophic lateral sclerosis. At the post-mortem examination I noticed small areas of decortication over both occipital poles, especially the right. On reading the history of the case we found a note that the patient had been knocked down by an ambulance about nine years before, and sustained a fracture of the skull. He was unconscious for three hours and was off work for six months. He had had no sequelæ and there did not seem to be any relationship between this injury and the disease of which he died. In this case Weigert-Pal sections of the brain show areas of pallor round the anterior horn of the right ventricle and to a less extent, round the anterior horn on the left side.

Case II.—A woman aged 44 who came into hospital with symptoms of sciatica died of bronchopneumonia. She had been knocked down in the street eleven years before, sustaining a fracture of the skull. She was said to have known nothing for a week and to have suffered from headaches for some months after the accident, but as she was of a hysterical disposition these statements may be to some extent discounted. She had not suffered from fits or from any other disability which could be attributed to the accident.

At the post-mortem examination an area of superficial loss of cortical tissue was found over the outer surface of the right temporal lobe (fig. 2). Further examination of the brain showed an area of poorly myelinated tissue of similar character to that seen in Case I round the outer surface of the anterior horn of the right lateral ventricle.

These cases suggest that the area round the anterior horn of the lateral ventricle is particularly susceptible to damage or reactionary œdema in injuries affecting primarily more posterior parts of the brain.

Histology of brain injury.—The finer changes in the brain have been studied by a number of authors both under experimental conditions and in human cases. The work of Rand and Courville is perhaps the most important owing to the large number of cases examined and to the careful technique employed. They found changes in all the elements of the nervous tissue in the most damaged areas. The axis cylinders in the neighbourhood of the injury were ruptured or injured in such a way that they underwent what Cajal called "preservation necrosis". The microglia reacted to the

injury within a very few hours but did not form fat granule cells till about three days after the injury. The oligodendroglial cells underwent acute swelling and later some proliferation. The astrocytes, if they were not damaged by the wound, reacted by swelling of the cell-body with a less or greater degree of fibre formation. These observations for the most part agree with those of other authors. Rand and Courville's observations on the nerve-fibres, however, are new, and are of special importance as indicating that these are directly affected by the mechanical injury.

Many authors have described alterations in the nerve-cells in the damaged areas of the brain. According to most they may be shrunken or swollen, and tend to stain darkly (Marburg, 1936). The nucleus also stains darkly and is often eccentric. These changes often resemble those found in cortical ischæmia, but that does not mean that they are necessarily due to ischæmia, and the presence of similar changes in the anterior horn-cells of the spinal cord in cases of spinal concussion seems to be against this suggestion. In bruised areas the nerve-cells show various stages of necrosis. Sometimes they absorb blood pigment, even at some little distance from a hæmorrhage, although this may be a post-mortem phenomenon.

Some authors, notably Rosenhagen (1930), have described "areas of paling" in the cortex, and consider it possible that the symptoms of post-traumatic dementia may be due to this change. The evidence that these areas may result from cerebral injury is, however, very ambiguous. In Rosenhagen's case the injury was not severe, and the authors say nothing about the blood-pressure or the condition of the arteries and kidneys. Rand and Courville (1936) in their studies, observed " areas of cell loss " chiefly in close relation to cortical hæmorrhages or infarctions, in the most damaged areas of cortex. Only in one case out of 18 in which the whole brain was examined did they find the " areas of paling " to be widespread in the cortex. In this case, that of a woman aged 58, who died six and a quarter hours after being struck by a motor car, they were confined to the right side of the brain, which was said to be otherwise normal. The short time between the injury and death, as well as the age of this patient, make it less likely that these areas of paling were caused by the accident than that they had been present before.

In a case reported by Winkleman and Eckel in which these areas were present, they state that there was endarteritis of the small vessels to which they might have been due, although they were inclined to attribute them to œdema. The evidence so far available therefore does not give much support for the relation of these areas to injury. If they may occur six and a quarter hours after injury we should expect to find them in almost every case in which the injury was at all severe, whereas they are comparatively rare findings. It must also be remembered that the previous medical history is rarely obtainable in cases of fatal cerebral injury so that the presence of hyperpiesis or renal disease might not be known.

The histological changes in the vessels and the hæmorrhages and ischæmic softenings to which they give rise have been thoroughly studied by many writers whose observations agree within fairly close limits. In addition to hæmorrhages which obviously result from the tearing of smaller or larger blood-vessels, all emphasize the frequent presence of ring hæmorrhages similar to those seen in poisoning by coal gas, arsenicals, or other poisons. The generally accepted explanation of these ring hæmorrhages is that they are caused by blockage of a small vessel with hæmorrhagic infarction around a small necrotic area. The diapedesis of red cells is therefore an indirect result of ischæmic change in the tissues. Their occurrence in cases of poisoning by coal gas and other poisons has been attributed to a reaction on the part of the endothelium of the small vessels of sufficient intensity to lead to blockage or thrombosis. Such a reaction may be found in cases of head injury in relation to the most affected areas. I have found it, for example, on the margin of the bruised areas of cortex in a patient who died forty-eight hours after head injury.

Another unexpected finding which is commented on by many writers is the occurrence of fat embolism of the cortical vessels. This results in diffuse infarctions

or wedge-shaped softenings of the cortex and subcortical white matter which differ from the results of direct contusion in affecting the cortex in the depths of the sulci as well as that on the surface of the convolution. Fat embolism seems to be most frequent in motor-car accidents in which there is also fracture of ribs or long bones and may cause death with cerebral symptoms in patients who have had no direct injury to the head, or only slight concussion.

As to the later changes in the vessels associated with late traumatic hæmorrhage there is less evidence. Rosenhagen cites a case of late hæmorrhage in which he found hyaline degeneration of the walls of the vessels in the neighbourhood of the hæmorrhage. It has recently been suggested by Kahlau that aneurysms on the circle of Willis may be caused, in predisposed subjects, by head injuries, but they occur so commonly in patients who give no history of head injury that the relations of cause and effect must be examined with more than usual care before we accept this view. No doubt the bodily effort often associated with an accident, and the sudden changes of intracranial and intravascular pressure which it may cause may lead to rupture of an aneurysm which is already present. On the other hand the accident may be caused by the aneurysms. For example a bicycling accident may be caused by the leakage of an aneurysm, or a workman may fall from a height owing to sudden giddiness or unconsciousness. In such cases, when there is gross hæmorrhage into or round the brain, it is easy to attribute it to the accident and to miss the small aneurysm from which it comes.

Histological study therefore adds to the gross appearances of bruising and hæmorrhages, changes in the nerve cells and fibres and in the walls of the vessels, and evidence of œdema. But these changes are all local, chiefly confined to the vicinity of the blow or the area of contrecoup. Histology gives no evidence of widespread damage to nerve-cells. As we have seen, there is reason to doubt the relationship of widely scattered areas of paling to the injury, and in fact it appears that loss of nerve-cells rarely occurs except in relation to hæmorrhages. While the bruised area is, as has been shown, completely absorbed, the nerve-cells in its neighbourhood survive, and when examined after a lapse of time are quite normal. It would appear, therefore, that the nerve-cells are not much more easily damaged by trauma than are the walls of the capillaries.

Is there then any more evidence of damage to axis cylinders and myelin ? It has been seen that the axis cylinders may be broken across either in the cortex or the underlying white matter, but this also appears to be a very local effect. The myelin also suffers, but we have evidence that this is rather a secondary result of œdema than a primary damage.

But although histological study has not yet told us why a blow on the head produces certain symptoms, it has, I think, given us some idea of what happens in the brain tissue at the moment of the blow. Further, when we compare the histological effects of brain injury with those of natural or experimental disease, we are better able to form an opinion on the various theories which have been advanced.

Theories of Concussion

These theories may be divided into the *vascular*, the *humoral*, and the *mechanical*.

Of the *vascular* theories, that which holds most vogue in this country is Trotter's modification of Kocher's theory. According to this theory deformation of the skull must always result in reduction in its cubic capacity. This causes a sudden expression of blood from the capillaries of the brain resulting in an equally sudden anæmia and loss of function of the nerve-cells. To this theory there are several objections. In the first place the sudden pressure resulting from a blow on the forehead or occiput might be supposed to increase rather than diminish the cranial capacity by making its shape approximate more closely to that of a sphere. And yet both with such blows and with the knockout blow of boxing, which probably does not cause any change in size of the supratentorial space, unconsciousness is as sudden as in lateral blows on

the cranial box. There is also no evidence at all that so temporary an emptying of capillaries, even if it occurs, will cause loss of function of nerve-cells. Injections of thorotrast into the internal carotid artery deprive a large area of the capillary bed of blood for almost a second, but do not usually cause any loss of function of the area involved. No doubt sudden loss of consciousness may follow continued anoxæmia of nerve-cells, as in the observations of Lennox and the Gibbs in which consciousness was lost abruptly six to eight seconds after the heart had stopped beating. But it seems unlikely that nerve-cells would suffer from anoxæmia after so momentary a deprivation of blood as is postulated in Kocher's theory.

Humoral theories.—Let us pass then to the theories, of which Duret's is the classical example, which hold that the phenomena of concussion are due to a wave of cerebrospinal fluid being driven from the lateral ventricles towards the foramen magnum. This theory has been strongly supported by Berner in recent years, and if the hypothesis on which it is based could be substantiated it would be attractive. These are, first, that a sudden blow on the skull could cause a wave of fluid to pass towards the foramen magnum at such pressure as to deform the walls of the 3rd and 4th ventricles and the iter of Sylvius, and secondly that the deformation of these areas could cause the clinical picture of concussion. That is to say that unconsciousness might be caused by sudden insults to the thalamus, the hypothalamus, or the brain-stem. It is of course held by many, with considerable justification, that the sudden temporary fall in blood-pressure, the vagus pulse, and the changes in or cessation of respiration which follow blows on the head, result from disturbance of medullary centres. And it would seem possible that a sudden deformation by a wave of cerebrospinal fluid acting on the sides of the thalamus or the genu of the internal capsule might produce loss of consciousness. But even Berner, the strongest modern protagonist of this theory, has been unable to produce evidence that such a wave occurs. If it did we should expect it to tear the walls of the iter of Sylvius, as well as to produce hæmorrhages round them. No one will dispute the frequency of small pontine hæmorrhages and dilatation of small vessels in the pons in cases of head injury, but it is very difficult to understand how those in the ventral half of the pons can be caused according to Duret's hypothesis. There is the possibility also that some of these do not occur at the time of the accident, but are related to later alterations of intracranial pressure.

As regards the walls of the *lateral ventricles*, small tears are more common and hæmorrhages perhaps less so (Gierlich). The demyelination round the anterior horns which has been described could also be made to fit in with Duret's hypothesis, and if it is modified to some extent it might explain them. The laws governing stress and strain between the brain tissue and the cerebrospinal fluid in the ventricles at the time of a blow on the head are a fit subject for research by physicists, who will no doubt before long give us a final answer to this question.

The theories of a *direct mechanical effect* on the nervous tissues may be divided into: (1) The compression theory of Sauerbruch and Breslauer. (2) The vibration theory of Marinesco. (3) The theory of deformation and stretching.

(1) The *compression* theory appears to be both incomplete and unsatisfactory. No doubt the bruising immediately under the point of impact may be caused by compression of tissues, but what of the contrecoup bruising? If the skull is more rigid and less easily moulded than the brain one would expect a negative pressure at the point of contrecoup. It has even been suggested that this negative pressure acting on the arterioles and capillaries from without makes them less able to withstand the pressure inside them and leads to their rupture. The compression theory is also shown to be unsatisfactory by the very local character of the lesions to the cortex under the point of impact. If sudden compression of nerve-cells may cause their death it seems unlikely that the transition from an area of complete necrosis of cortex to one in which the nerve-cells are quite healthy would be as abrupt as it is.

Blows on nerve-trunks may certainly cause temporary loss of conduction, and it is quite possible that this effect is produced by sudden severe compression. But a

local severe compression of a limited area of cortex is unlikely to produce either sudden loss of consciousness or more remote effects such as the disturbances of the vegetative nervous system which are so common in head injuries. To avoid this dilemma Breslauer postulated that the compression of the brain under the point of impact pushed the brain towards the foramen magnum and so affected the medulla indirectly.

(2) Marinesco's *vibration* theory is founded on the work of Meltzer, who killed bacterial cultures by vibration and on experiments of his own in which he produced physico-chemical changes in colloids by vibration. Its importance seems to depend on the answer to the question " How is the force of a blow transmitted through a gelatinous medium such as brain tissue ? " If it produces a rapid succession of waves of high and low pressure spreading out from the point of impact this could fairly be called " vibration ". But histological study does not support the view that the effects of the blow radiate from a centre ; they are widespread but focal, affecting the walls of the ventricles and the pons almost as much as that part of the cortex which underlies the point of impact.

(3) The theory of *deformation and stretching* seems to me to fit in best with the known facts. This theory supposes that the alterations in the shape of the brain which result from a blow on the head produce sudden stretching of nerve-fibres and other tissues, especially blood-vessels, not only under the point of impact but at various places in the brain especially where its movement is resisted by dural septa such as the falx and tentorium, or by the bony ridges of the base of the skull. This theory is no easier to prove than the others, but it does account for the widespread, apparently random, effects of injuries on the brain, for the tearing of blood-vessels, and for the disturbances of the vegetative nervous system. To be satisfactory it must also account for such effects as œdema and the local or more widespread dilatation of blood-vessels to which attention has been drawn by many writers.

These effects may be considered to result from lesions of the walls of arterioles and capillaries of such minor degree as not to rupture them. Stretching a small vessel may well damage its endothelial lining and, if it also damages the local contractile mechanism by which the cerebral arterioles react to changes in internal pressure, the vessels will lose their normal tone and remain dilated, whatever the pressure inside them may be. This theory was put forward by Knauer and Enderlen to account for the increased flow in the internal jugular vein which they found after experimental head injuries, and it has received recent support from the work of Fog who has conclusively proved the presence of this local contractile mechanism. It seems a more satisfactory way of accounting for dilatation of vessels than Ricker's theory of traumatic paralysis of vasomotor nerves.

A local dilatation of arterioles and capillaries, especially if associated with some damage to their endothelial lining, also seems a satisfactory explanation for œdema. The other possible cause for œdema is that the deformation of nerve-fibres or stretching of other tissues results in the formation of metabolites which make the walls of the capillaries more permeable. The only evidence in support of this theory is the observation of Knauer and Enderlen that the brain tissue near the area of impact became acid to litmus. Both processes may of course be at work in traumatic œdema as well as in the œdema round cerebral tumours and abscesses.

It is well known that bruising is much more easily caused in some individuals than others, and that it varies in different conditions of health. If this is also true of the cerebral blood-vessels it explains why minor cerebral injuries may sometimes result in unexpectedly severe vascular lesions in the brain. Another factor may play a part in traumatic cerebral hæmorrhage, especially when it occurs in the pons. Moore and Stern have recently emphasized the frequency with which pontine hæmorrhage occurs in cerebral tumours, and have related it to a rapid increase in supratentorial pressure often associated with uncinate herniation. The reactionary rise of pressure within the cranium after head injuries, whether associated with hæmorrhage or œdema, may well have the same effect. Certainly the pontine hæmorrhages in cases

of head injury on which Berner has laid so much emphasis do not appear to differ in any respect from those associated with cerebral tumours.

Among the most interesting effects of head injury are the immediate and delayed alterations in the vegetative functions. These have been recently studied by Kat, who has found the initial vagus pulse to be followed by a later lability of the pulse-rate and disturbance of its day-night ratio. He has also frequently found an early transient rise in the level of the blood-sugar. These effects suggest a lesion at the level of the hypothalamus.

The cause of loss of consciousness remains conjectural. We can only define consciousness in terms of reaction to stimuli, but when looked at from this point of view the seat of consciousness, if there be one, does not appear to lie in the cerebral cortex. This can be removed in cats without the loss of those reactions which we associate with consciousness, and large parts of the cortex can be removed in man without even transient loss of consciousness. There are also cases of head injury in which temporary loss of certain cortical functions, e.g. hemianopia, or loss of memory, occur without any initial loss of consciousness.

In cases of lesions of the brain-stem unconsciousness seems more likely to occur the nearer the lesion approaches the thalamus, so that both in experiments and in clinical experience the state of consciousness appears to be *centred on* the thalamus. This does not necessarily mean that it has *a centre in* the thalamus as Penfield has recently suggested, although that may be true. This brings us to the hypothesis that unconsciousness in head injuries may well be caused by a sudden deformation or stretching of important fibre tracts passing to or from the thalamus.

These effects on the thalamus and hypothalamus or the tracts passing from them might perhaps be caused by a wave of cerebrospinal fluid pressing against the wall of the 3rd ventricle. But it seems more probable that they are due to a sudden displacement of the cerebral hemispheres in relation to the incisura tentorii deforming or stretching the connexions of the hemispheres with the brain-stem.

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Section of Odontology

President—A. H. Parrott, O.B.E., M.D.S.Birm.

[*October* 24, 1938]

Jaw and Facial Injuries in War-time

PRESIDENT'S ADDRESS

By Arthur H. Parrott, O.B.E., M.D.S., L.D.S.

The recent war scare has brought back to many of us the fact that the last war ended twenty years ago, and we remember the chaos and lack of organization which existed at its outbreak in August 1914, particularly with regard to our own profession. There was no Army Dental Corps worth considering at that time and the necessity for one was absolutely unrecognized, even by the Royal Army Medical Corps, whose ranks were barred to dentists without medical qualifications. The War Office and Admiralty had long waiting-lists of applicants for dental appointments, with no use for them, and many of our younger men joined up as combatants (all honour to them) involving a waste of specialized trained material which the country could ill afford. Medical examination of recruits at last revealed to the authorities the desperate need for dental service, and gradually the Dental Corps evolved. Its work in the Army has survived the War and I believe it to be to-day a fine organization, well equipped for military dental service as far as the maintenance of a fair standard of dental fitness in the armed forces is concerned.

More slowly came the recognition of the need of dental service in the major work of war casualties; jaw and facial injuries were a new thing. Royal Army Medical Corps surgeons did their best, entirely ignorant of the value of dental assistance, until at last the gallant volunteer work of some of our leading hospital teachers bore fruit; their surgical colleagues began to recognize the essential nature of their assistance, and jaw centres were tardily established in the military commands. But meanwhile, all over the country, men with shattered jaws and mutilated faces wandered in search of treatment which was non-existent. In hundreds of these cases constant sepsis, cicatrization, contractions, and distortions, resulted in months of unnecessary and often hopeless efforts to restore anything approaching normal function and appearance. It was grim tragedy for the men who suffered and for those who tried to help them. Here and there one meets with one of these scarred and shattered heroes, but to us as a profession they have become a memory only, and war-time jaw surgery has gone back into its pigeon-hole. Will it be dragged out again in England, and if so, in what condition and under what conditions? Shall we start again, when the first bomb drops, with the tardy organization of what should be a ready-equipped line for first-aid treatment, so that we, as a profession, may be able to act as our trained hands and minds should enable us to do, in close co-operation with our medical and surgical colleagues, both in civil and military hospitals? Or will there be again that period of chaos and lack of the team work—so essential in these cases? It is with these thoughts in my mind that I have chosen my subject to-night. I am fully

aware that in this audience I may be preaching largely to the converted, but twenty years is a long time, and a new generation of dental surgeons has arisen, comparatively few of whom will be able to take up the work where it was left off, should the grim necessity arise.

Another appalling thought is that to the military casualties with which our profession may be called upon to deal, may be added an extra demand for similar treatment for civilian casualties. The air-raid precautions which are being forced upon us now should serve to point to the huge extension of the surgical and medical calls that would arise, and I visualize the futility of a few highly specialized centres, military or civilian hospitals, being called upon to attend to the demand which would or might develop.

Ignoring for the moment other forms of injury or disease, jaw cases are dental cases primarily and surgical cases secondarily. The surgeon, however skilled he may be, will not, if he is also wise, attempt surgical treatment on a shattered face or jaw until he is assured that the oral cavity has been dealt with first and put in as favourable a condition as possible before he attempts surgical manipulation on the external parts. That was the lesson taught us by the first year of the Great War, and it cannot be too strongly reiterated now. My own experience, when commencing jaw work at the First Southern Command centre, was that of many other colleagues. The surgeon-in-charge said : " These are my cases ; I will call you in when I want you." The result was lamentable ; surgical operations were performed without regard to the severe internal sepsis due to broken teeth, bone fragments, &c., and case after case went backwards and brought a string of unnecessary complications and problems in remedying the primary dental neglect with it. Fortunately our surgeon changed, and the late Professor Billington (then Captain Billington) took charge. His attitude was exactly opposite : " These jaw cases are dental cases first ; call me in when you want me." The case-histories became entirely changed, and his wisdom earned heartfelt gratitude from his dental colleagues ; co-operation was fully and freely given, and masses of complications disappeared when treatment was put on to this logical basis. I find myself wondering how far that axiom of Professor Billington's is recognized by our surgical colleagues of to-day. I hope far more generally than I imagine, for without its acceptance we shall find ourselves once more struggling in a sea of avoidable difficulties and complications if ever the need for jaw surgery on a military footing should arise again in this country.

Following this argument, I think it should be made plain in what ways the dental surgeon is to be of value to the surgeon by the early co-operation for which I have pleaded. These are :—

In diagnosis : All cases of fracture may not be obvious to a surgeon and yet be detectable by the dental surgeon owing to some slight abnormality in occlusion of teeth, &c.

In prevention of sepsis internally, from compound fractures open to the mouth, by : (*a*) Removal of carious, broken, or septic teeth and roots, fragments of bone where necessary, and foreign bodies (shrapnel, clothing, &c.). (*b*) Manipulating fractured jaws into normal alignment as far as feasible, retaining same and putting parts at rest by wiring, temporary splinting, &c., whilst providing for nourishment.

In brief—in cleansing wounds ; resetting fractures ; giving rest by retention.

How is this co-operation of surgeon and dentist to be provided for on a general scale ? I am not forgetful of the fact that full team work for complete treatment of jaw cases necessitates other branches of skilled science ; radiography is essential, anæsthesia, bacteriology, photography, and last, but highly important, skilled mechanical dentistry. These can be organized in hospital centres, and the War Office Report framed in 1932 by a specially appointed standing Committee, including Mr. Kelsey Fry, Sir Harold Gillies, and Mr. Warwick James, has relieved any doubt in my mind as to the preparedness of our Army Dental Services.

For dealing with civilian casualties a similar but more elastic scheme will be needed. May I urge that the attachment of local dentists to first-aid units, to be called upon as necessity arises, if and when such units are mobilized, should be an integral part of our civilian organization? Doubtless in time some such arrangement will find a place in the vast organization of our population on a defence basis, but I feel strongly that our profession as a whole must play its part in framing a scheme, at once systematic and elastic, which will enable us to make use of our opportunities of service to the best advantage of the community. And to do this, it will not suffice merely to enrol our names as willing to serve in local units. Facilities should be found for the rank and file of the profession to gain the rudiments of instruction necessary for them to render adequate first dental aid in cases which may well be quite outside the routine practice of dental surgery. Such emergency measures seem to be covered by the following list :—

Diagnosis of fractures (crepitus, mobility, loss of alignment or occlusion of teeth, &c.).
Control of hæmorrhage and danger of suffocation.
Cleansing and irrigation of facial wounds.
Removal of foreign bodies, tooth and bone fragments, &c.
Reduction of fractures.
Temporary fixation by wiring or ligatures ; compo splints ; bandages ; adhesive tape.
Provision for feeding.
Suturing wounds, flaps, &c., in emergency.

To advertise to our rank and file the need of some study and instruction in maxillo-facial treatment, a simple emergency dental outfit might be standardized and made available through surgical and dental depots, and every dentist enrolled should be provided with it. I had almost suggested that such an outfit should be a Government issue, but that is, I fear, beyond expectation. Such outfit suggested to deal with first-aid conditions on the simplest lines might include the following : (1) Pocket torch ; (2) mouth mirror ; (3) tweezers (dissecting) ; (4) syringe ; (5) antiseptic : (tabloids) iodine ; (6) ligatures, wire, &c. ; (7) adhesive strapping ; (8) bandages ; (9) lint (absorbent) ; (10) artery forceps ; (11) hypodermic syringe ; (12) morphia ; (13) sutures and needles.

The above are merely haphazard and tentative suggestions ; it would be a matter for a little careful collective thought to add essentials or eliminate non-essentials. At the best a skeleton outfit of this type would be readily amplified from the dental surgery. Such things as metal trays, compo for use as temporary dental splints, forceps, elevators, &c., would probably be added by many to the nucleus provided by the small and portable first dental aid outfit. I am not qualified myself to elaborate the idea further, having had no actual front-line experience, but I put emphasis on the idea because we are considering conditions where dressing and clearing stations, as organized in the Army, would need to be represented throughout the country by volunteer A.R.P. bodies in possibly very loose formation. Further development would be possible in team organization, when essential dental appliances should be included in every first-aid outfit of any size, rising to the more complete stocking and furnishing of motor ambulances and temporary hospitals (halls, schools, &c.), the provision of which would necessarily be greatly extended in any complete scheme of national defence on modern lines.

Thus far I have spoken only of the problem of organizing dental service in collaboration with first-aid medical organizations, and air-raid precautions units and formations, as they may arise, and I sincerely hope our dental associations will take the matter up and assist us as a profession to achieve some measure of organization which may be of practical value in the face of national war-time emergencies. Cities and factories, munition works, aerodromes, towns, villages even, will all have their needs and place

in a general scheme; real service will not be achieved without a great deal of organizing spade-work.

I have tried to lay stress on the importance of this civilian front-line dental work because we learned so much, from our Great War experiences in treating jaw and facial injuries, of the vital import of early dental treatment. In ordinary civil practice fractured jaws, which are not really a numerous class of hospital cases, do not as a rule involve immediate loss of substance, as is the case with most gunshot or shell injuries. The treatment even of a simple fracture, does not always result in a prompt and perfect restoration; with one broken tooth present the advent of sepsis may complicate matters seriously. With loss of substance, problems multiply exceedingly and the whole resources of a hospital team may be needed to deal with a single case; medicine, surgery, dentistry, mechanical dentistry, radiography, bacteriology, photography, and plastic surgery, may each and all be called upon to contribute to the treatment of a case. Such treatment can only be achieved in an organized centre, and here I would stress the importance of the mechanical side being well equipped with first-class mechanics, to help the dental surgeon by supplying dental or inter-dental splints and appliances of all sorts which may be of infinite variety in construction and material, every case being a law unto itself.

Bone-grafting.—One big problem which was solved in many cases successfully was that of bone-grafting in the case of fractured mandible. It was solved largely by repeated failure bringing unexpected facts to light.

In the First Southern Command Jaw Centre Professor Billington, after many successes and failures with us, evolved principles of treatment which proved so sound eventually that one found it hard to realize why we had not recognized them at the outset. There is one important point about his method which I would like to mention; he used no wiring of the fragments to the graft, which simply lay in broad contact at each end of the jaw fragments, overlapping them in a bed of healthy tissue. Previous to operation the parts had been put into alignment by splints; at the grafting operation all splints were removed, being replaced only after the external graft wound had healed, when the parts were easily restored to their proper position. That wires have been successfully used to fix the bone is recorded by other writers, but often they gave rise to troublesome sepsis and sinuses and endangered the life of the graft and its union. The simple laying-in of the graft and leaving it free till it was healed over proved in Billington's hands one hundred per cent. successful in obtaining osseous union without sepsis (*Proc. Roy. Soc. Med.*, 1919, **12**, Sect. Odont., 55–72).

In our earlier efforts at repairing fractures we were largely governed by the idea that complete rest for the parts could only be obtained by complete fixation and that any movement at all would be an encouragement to sepsis. One element of fallacy showed itself later in this argument when it was realized that if the osseous and dental hard tissues were rigidly fixed, the muscle attachments were more heavily strained by their inevitable tension during speech, deglutition, &c., and therefore the aim of splinting became not so much absolute rigidity, but a balanced rest and restraint for hard and soft tissues, allowing free circulation of blood with minimum disturbance of cellular activity. I think that principle is the sounder; if it were not so, healing and healthy union would seldom be attained in edentulous cases in which real rigidity cannot be achieved. One calls to mind also cases in which an extra-oral bandage only has been used, with unexpectedly good results. There again is a simplification of the mechanical difficulties, parallel to the simplification of Billington's bone-grafting methods.

Aviation accidents.—Another class of jaw injuries which particularly interested me during the Great War was that of aviation accidents. The First Southern General Hospital, to which I was attached, received a number of these from neighbouring aerodromes, and facial injuries caused by crashes showed a large percentage of a constant type which we attributed solely to one cause—the striking of the aviator's

face against the coaming of the cockpit of the plane, as the head was thrown forward to receive what came to be known as the " hammer-blow ".

According to the severity of impact, the result was a broken tooth, a broken jaw, or a broken skull. Fractures of the mandible or maxilla or both (seldom both) were usually of a type directly traceable to a common cause, and my colleague, Mr. Harold Round, and myself, spent much time and effort trying to induce the Air Ministry to have planes provided with a special cockpit padding to minimize the effects of this particular accident. Things were extremely hard to move, for with the whole of the Medical Research Board behind us, the Technical and Equipment Boards held fresh ideas at arm's length. At the close of the War we had the satisfaction of knowing that at least some hundreds of training machines had been treated as we suggested.

Novices in flying are more prone to suffer this particular damage ; the expert senses a coming crash, possibly in time to crouch and protect his head, whereas the learner clings desperately to his joy-stick to the last moment.

It is not, however, my object in this paper to give any sort of full description of war-time oral surgery methods. These cannot be covered in a profitable and practical manner in one address, but sufficient literature is available to open the minds of those who feel ready to equip themselves to the best of their ability for the service of the nation and common humanity, and from that literature may be extracted sound and simple principles, bred from the hardly-won experience of the comparatively few men who wrestled with these problems during the Great War.

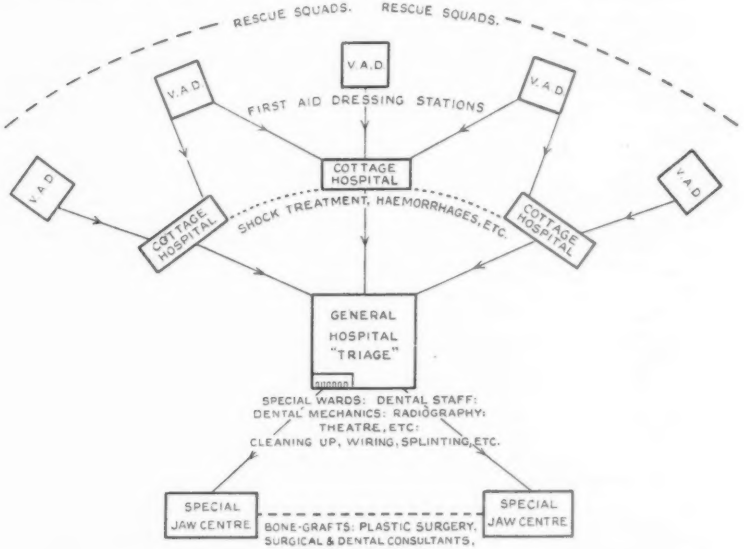
We have all, I think, received forms issued by the B.D.A. or Public Dental Service Association asking for information as to how, when, and where, we could volunteer our services as dental surgeons. The replies to that circular will at least give a nucleus on which to build. And, whilst trying to crystallize my own ideas for this address, I found a brief editorial letter " To all readers " in the *Public Dental Service Association Journal* for this month, giving me hope that the necessity for organization on a wide scale is being foreseen. It concludes :—

> " In the meantime the most useful thing that members of the profession can do is to take such steps as may be within their power to arrange their own affairs in order that any urgent change of circumstances may be carried through with as little delay and as little dislocation as possible and for the rest, hold themselves in a state of cheerful and resolute preparedness."

With this I think we shall all agree whole-heartedly, and as I see it, it is incumbent upon members of this Section to encourage with all their power the spread of such emergency knowledge, and to use every means in their power to help forward the essential collaboration and pooling of ideas and actions with our surgical and medical brethren, which alone can produce the real team work—which, again, alone can produce any worthy result and reward for such skill and effort as we may be able to offer.

Personnel.—To be prepared as a profession the question must be asked : How best can our special work and skill be made use of for the common strength ? Beginning with the youngest rank, our dental students, I venture to give you the opinion of the Dean of the Birmingham Dental School, Colonel Howkins, whose wide experience of war conditions gives great value to his opinion. It is this : All students who have received any instruction in anatomy and physiology and have some first-aid knowledge should not be enlisted but should be attached as dressers to civilian dental surgeons who should be appointed to attend at hospital centres. At the present moment there is a big drive in progress in Red Cross work ; the number of V.A.D. workers in Birmingham rose quite recently from 200 to 500. All these will have received some first-aid knowledge in connexion with general casualty work including jaw injuries. After cases have been dealt with at the outset by these first-aid agencies, they will be transferred to local or cottage hospitals (in large centres possibly direct to a general hospital) where jaw cases (unless, of course, complicated by major injuries or disease)

may be segregated and treated by dental surgeons and student dressers, already attached. Here the necessary cleaning-up, operations, removal of foreign bodies, broken teeth, shrapnel, &c., may be performed, and the parts put at rest as far as feasible by ligaturing, temporary splints, bandages, plaster, &c. For more complete and advanced treatment, the cases will then be sent to special hospitals where maxillo-facial injuries may be dealt with by a fully-qualified surgical and dental staff, who will act together as a unit or team in the highly skilled work entailed in interdental splinting, bone-grafting, plastic operations, &c. Here also must be found a ready staff of highly skilled mechanics, with adequate laboratory (vulcanizer, casting outfit, &c.), to carry out the often intricate type of mechanical devices involved.



Radiography, bacteriology, photography, electrotherapy, are other departments which may be called upon, and my hope is that facilities for the collaboration of these specialities will be organized and provided for in any scheme of hospital treatment which our authorities may put before us as a profession, the whole resources of which would then be at the service of the nation to its best advantage.

This outline of a possible scheme (see diagram above) is, of course, only suggestion on my part, but it is at least an ideal to aim for.

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Section of Comparative Medicine

President—THOMAS DALLING, M.A., M.R.C.V.S.

[*October* 26, 1938]

A Review of Some of the Recent Contributions to Disease Problems of Domesticated Animals

PRESIDENT'S ADDRESS

By THOMAS DALLING, M.A., M.R.C.V.S.

DURING the past two decades our knowledge concerning the nature, cause, and prevention of many of the familiar diseases of domesticated animals, has been considerably increased. In some of the investigations leading to the present state of knowledge I have been sufficiently fortunate to have played some part, and though I must to-day refer to conditions of which I have little first-hand knowledge, it will be with some of my own work that I shall deal in more detail.

Twenty years ago when I first entered the field of research into the causation, nature, and prophylaxis of diseases of animals, the position differed greatly from that which exists to-day. There is evidence that during the immediately preceding period a considerable amount of important work had been accomplished, and its results were that many of the important scourges had either been entirely eliminated from this and other countries or were under control. It would be unworthy of this occasion if I did not pay tribute to those pioneer workers in this field for the position in which we found ourselves twenty years ago. There had been, however, lack of concentrated effort in detailed research, owing mainly to the fact that the interested workers could only devote time spared from other important duties to the problems confronting them and also to the imperfect knowledge of many of the fundamental processes intimately bound up with these problems. There had also been a tendency to isolation by the workers concerned, and though that may exist in a small measure even to-day, we now find workers trained in many branches of science all participating in research work to the common good of the investigations in hand. The birth of the Section of Comparative Medicine was an important step forward in the present-day collaboration and I feel that, were its founder—Sir Clifford Allbutt—alive to-day, he would be happy in the knowledge that his efforts had borne abundant fruit. I do not intend to refer in detail to many of the valuable contributions to our present knowledge, but propose to deal with the general position of prophylaxis and control of some of the diseases which have caused, and are still causing, losses among our domesticated animals.

ANAEROBIC INFECTIONS

I will deal first with some of the anaerobic infections of animals. Throughout the world the important anaerobes giving rise to diseases in animals all belong to the Clostridium group. They are *Cl. chauvœi*, *Cl. septique*, *Cl. welchii*, *Cl. œdematiens*, *Cl. botulinum*, and *Cl. tetani*.

Cl. chauvœi.—This anaerobe has long been recognized as the cause of blackleg or blackquarter in cattle and sheep in various parts of the world. There was, however, some doubt as to the specificity of the infection set up by this organism, for other bacteria, e.g. *Cl. septique*, *Cl. welchii*, &c., were believed by some to play quite as

important a part in the causation of blackleg. Some of the misunderstanding was undoubtedly due to the lack of accurate knowledge of the essential distinguishing characters of *Cl. chauvœi*, and much of the credit for putting our knowledge of anaerobes generally on a sure footing must go to workers of the Medical Research Council—e.g. Miss Muriel Robertson—during and soon after the Great War, and to American workers—especially Hilda H. Heller, who was able to show that *Cl. chauvœi* had its own special recognizable characters and that many of the cultures labelled *Cl. chauvœi* were either contaminated with other anaerobic bacteria or were cultures of some other organism. Credit must also be given to Zeissler and to Weinberg for their work on purifying anaerobes.

For a long time past methods have been practised in the field for the prevention of blackleg. They consisted mainly in the injection of infected muscle or of attenuated cultures and though they were attended by some loss from actual infection, the degree and incidence of immunity conferred was apparently high. The use of natural aggressins and later, filtrates of pure cultures of *Cl. chauvœi*, was adopted, and again the degree of protection, as demonstrated both by laboratory and field trials, was high. More recently the use of formalinized whole culture has been explored and found efficient, and is probably the most widely adopted method of immunization. The immunization against *Cl. chauvœi* infection cannot be passed over without reference to the work of Henderson, who showed that the pure " O " antigen is a powerful immunizing agent. We owe much to Henderson for his work on this and other anaerobes and especially for the method which he devised for testing immunity in laboratory animals. *Cl. chauvœi* seemed to differ from other pathogenic anaerobes in its failure to produce a soluble toxin. It has recently been demonstrated by Mason that, under certain conditions, a toxin may be produced. Mason showed that in culture filtrates two antigens were present—a toxin and a heat-stable antigen. The toxin is capable of stimulating antitoxin production but, on the other hand, Mason produced evidence to show that it was capable of being neutralized by—in addition to its specific antitoxin—*Cl. septique* antitoxin and, to some slight extent, by serum of apparently normal bovines and rabbits. Mason agrees with Henderson, however, that the heat-stable antigen is the important agent in the production of immunity to *Cl. chauvœi*. The use of the heat-stable " O " antigen has not been adopted in field work, largely I think, because of the lack of a simple method of preparation. Its great advantage would be its safety, and one can foresee its general application provided its preparation was economical. Within recent years it has been shown that infection with *Cl. chauvœi* may occur in certain districts following injury to the genital tract in sheep during the act of parturition. It has also been demonstrated that an antiserum produced in horses by repeated injections of the filtrate of *Cl. chauvœi* will prevent the infection.

Cl. septique.—Though *Cl. septique* has been known to be associated with blackleg-like diseases of cattle and sheep in some localities, its importance in animal husbandry mostly concerns sheep, in which animal it gives rise to the disease termed " braxy ". This disease is commonly found in certain parts of Great Britain, especially in some districts of Scotland and North Wales, but it also occurs in Iceland and in Scandinavian countries. Previous to the investigations of Gaiger in Scotland, an anaerobe had been isolated from sheep affected with " bradsot " or braxy, in Norway by Ivan Nielsen, and in Iceland by Jensen. It was Gaiger, however, who first showed that *Cl. septique* was the organism associated with the disease and that the organisms isolated by the above workers were also *Cl. septique*. (It is to be noted that braxy or bradsot, as described in Germany and investigated by Zeissler, is not similar to that in Scotland, &c., and that the associated organism is not *Cl. septique* but *Cl. gigas*—an organism of the *Cl. œdematiens* type.)

Gaiger, with whom I had the honour to be associated in his work, realized early that it was impossible to carry out investigations into microbial diseases of sheep

unless the sick animal was observed and killed for examination. The older researches on sheep-disease problems, by workers like Hamilton, McGowan, &c., broke down because of their failure to observe this essential point, and much of their work is thereby misleading.

Gaiger's work on braxy marked the beginning of a new era in connexion with sheep diseases generally. There had been a lack of precise knowledge concerning any of the important diseases affecting sheep. Gaiger's methods opened up possibilities of field researches which since his time have produced much of the information we now possess. For preventing braxy in the field Jensen used a suspension of spores of *Cl. septique* with an appropriate dose of antitoxin. Gaiger replaced this method by the use of toxin alone, suitably diluted, and for some years this method was practised with satisfactory results. Later, however, it gave place to the use of an under-neutralized toxin-antitoxin mixture, in which toxin of high potency was used. The credit for the introduction of this method belongs to Allen and Bosworth who, in addition, showed that sheep could be immunized concurrently against *Cl. chauvœi* and *Cl. septique*. Eventually the use of a formalinized whole culture was adopted and is now largely practised in this country.

In connexion with *Cl. septique*, Henderson has shown that an active antibacterial immunity can be established by the use of pure " O " antigen, and that the immunity so established is as effective against infection as the immunity produced by the elaboration or injection of specific antitoxin. This finding raises a most interesting and important immunological question concerning the toxigenic anaerobes. *Cl. septique* produces a powerful toxin in culture and in the animal body, and a highly potent specific antitoxin can be produced artificially. Craddock and Parish demonstrated that a requisite dose of this antitoxin would prevent death or symptoms of illness in mice previously injected with cultures of *Cl. septique*, provided that the interval between the infection and the administration of the antitoxin was short. Henderson, on the other hand, produced evidence that a high degree of immunity against culture infection was set up by the use of " O " antigen following which antibodies were produced without any evidence of antitoxin. At first sight these findings may seem to be definitely contrary to one another. Apparently the explanation is that both may be correct. Henderson's experiments dealt with pure anti-bacterial infection, and it would seem that after infection with *Cl. septique* the organisms must multiply locally before toxin production can take place. The immunity engendered by " O " antigen is sufficient to prevent this occurring to any great extent and thus little or no toxin is produced. On the other hand, in the prevention of illness by the use of antitoxin, the organisms may multiply in situ, but any toxin elaborated is quickly neutralized by the circulating antitoxin.

Till Henderson's work was carried out, some doubt existed concerning the ability of dead or killed organisms (anaerobes) to stimulate the production of immunity. His work clearly indicates that there is no necessity to suppose the presence of living organisms, and also that immunization by means of formalinized whole culture is superior to others, because it is likely that the heat-labile " H " antigen also plays an important part in immunization.

Cl. welchii.—Probably the most interesting group of pathogenic anaerobes is *Cl. welchii*. Till about 1922, it was assumed that *Cl. welchii* represented a single group with minor differences within the group. The production of a toxin was recognized and the part played by *Cl. welchii* in the causation of gas-gangrene in the human subject was known. It was not till work on a disease of sheep—lamb dysentery—was in progress that important differences were shown to exist within the group. The association of *Cl. welchii* with this disease was established by its occurrence in the intestine of affected lambs and, at a later date, it was shown that it was only on rare occasions that the organisms invaded important tissues, the pathogenic effects being caused by the toxin elaborated in the intestine and absorbed therefrom. Laboratory

tests soon showed that the strains recovered from affected lambs differed materially from classical *Cl. welchii*. The biochemical difference was small, but the difference of the toxin produced was very apparent, especially with regard to its potency and its power to hæmolyse red blood-cells.

A further difference became apparent when antitoxin production was studied, for whereas the antitoxin produced by this new strain neutralized equally its own toxin and that of classical *Cl. welchii*, the antitoxin of classical *Cl. welchii* neutralized only its own toxin. It appeared, therefore, at this stage of the investigations, that the new strain of *Cl. welchii* had the power of producing a toxin which contained the toxin produced by classical *Cl. welchii* with, in addition, some extra element. Soon a further type of *Cl. welchii* was isolated—again from sheep. McEwen, working on a disease of young sheep in Kent, isolated an organism which possessed some of the characters of *Cl. welchii*. This organism and its toxin seemed to have much in common with the lamb dysentery strains, though following further research, it became evident that in some cases the antitoxin from McEwen's organism failed to neutralize the toxin produced by the lamb dysentery strains. It was obvious that the McEwen strains differed from the classical strains in that they produced toxin containing some extra element, and that the lamb dysentery strains contained that same extra element with probably a further additional element.

It was from Australia (Bennetts), New Zealand (Gill), and Tasmania (Oxer), that the next development was recorded. These workers independently isolated a further type of *Cl. welchii* which had apparently some relationship with McEwen's strain but had much more in common with the lamb dysentery types. Soon after these observations were recorded, Montgomerie and others isolated a similar type of *Cl. welchii* in sheep in this country. It remained for Wilsdon to study these types of *Cl. welchii* and he grouped them into four types according to their toxigenic factors. Glenny and his co-workers also studied these strains and pointed out that it was not sufficient to adopt Wilsdon's classification, for it was possible to show that the recognition of toxins produced by the various members of the group (five in all) varied according to the methods employed for their demonstration. The following table illustrates the correlation between the findings of Wilsdon and Glenny.

		Toxins				
Type		α	β	γ	δ	ϵ
A	..	+	−	−	−	−
B	..	+	+	+	+	+
C	..	+	+	+	+	−
D	..	+	−	−	−	−

Investigations have now shown that all four types are more commonly found than was formerly believed but, so far as I know, only Type A, i.e. classical *Cl. welchii*, has been found in human beings.

In sheep the various types produce their toxins in the alimentary canal, and by suitable tests it is fairly easy to establish the type of toxin present. Many interesting observations have been made concerning this group in sheep. Roberts recently has demonstrated, in some measure, how the state of acidity and the amount of milk in the stomach of the lamb influences the production of the ϵ type of toxin. Bosworth and Glover demonstrated how the action of trypsin can accentuate the degree of toxicity of the same toxin. Dalling and Ross have shown (in a paper in the Press) how different types of toxin may be found in the same sick lamb, and point out how unreliable it is to classify the toxin-producing organism unless it is given every facility to produce all types of toxin. They also discuss the conditions necessary for the production of the various toxins by the various types of *Cl. welchii* under artificial conditions. This would appear to have an important practical bearing for, in the prevention of such toxæmias in sheep, it is possible to make use of antigens and anti-

toxins against the various toxic elements. Unless it is certain that only one type of toxin is being produced—to the total exclusion of the others—it would seem to be advisable to use antigens or antitoxin containing all the various elements.

It has been clearly demonstrated that infections by this group can be prevented by the use of vaccines or by antitoxins. A simple but unique method of immunization has been worked out. Lamb dysentery may attack the lamb when a few hours old. Although in many districts it is possible to protect the lamb by injecting antitoxin soon after birth, in others, because of the system of farming, this is not possible, and it is necessary to immunize the lamb via its mother. We were able to show that the immunization of the mother does not result in the birth of an immunized lamb. We found, however, that the colostrum of the immune mother contains antibodies in a concentration much higher than that found in her circulating blood, and that the partaking of this substance renders the lamb immune within a few hours. The antibodies can continue to pass from the alimentary canal into the general circulation from birth till the lamb is about four days old.

The method in practice consists in injecting the mother-sheep with formalinized whole culture on two occasions, with a long interval between the doses, the second dose being given a few days before parturition so that immunity is high when the lamb is born. The first dose lays down a primary immunity and the second dose causes a rapid and extensive rise. If a solid primary immunity has been established during the first breeding year of the sheep's life, one dose each following year, just before lambing takes place, appears to be a sufficient stimulus to establish the necessary amount of immunity to protect the lamb. The important thing is to ensure that the lamb or sheep is protected against all the toxins that may be elaborated.

Cl. œdematiens.—This anaerobe may cause losses in sheep and cattle in this country, but it is in Australia that its presence seems to be of the greatest importance, since there it has been shown that the disease of sheep referred to as " black disease " is associated with its presence in the tissues. Dodd in 1921 recognized the disease as being caused by an anaerobe, but it was not till 1927 that Albiston and Turner and Davesne, working independently, identified the anaerobe. In 1928 Edgar demonstrated the presence of *Cl. œdematiens* in the livers of apparently healthy sheep in black-disease districts and demonstrated the interesting association of this organism and the liver-fluke parasite. It is apparently only when destruction of the liver parenchyma occurs—usually by the entrance of the immature fluke—that the organism is able to exert its toxigenic effects. In Australia, therefore, two methods can be adopted to prevent infection of sheep by *Cl. œdematiens*: (1) the prevention of fluke infestation, and (2) the immunization of the sheep against the organism by the use of formalinized whole culture. Both methods are used to-day.

In certain parts of Germany a disease of sheep is associated with the organism isolated by Zeissler and termed *Cl. gigas*. This organism has many of the qualities of *Cl. œdematiens*—differing mostly in size (hence its name). It may be that further research will reveal differences in the types of *Cl. œdematiens* somewhat similar to those pertaining to *Cl. welchii*.

Cl. botulinum.—I do not propose to say much concerning this organism except to point out that several types are recognized and that probably there is some overlapping, as occurs in the *Cl. welchii* group. The work in South Africa seems to indicate that this is the case, Types C and D being now recognized.

You are, no doubt, familiar with the work of Theiler and his school who found *Cl. botulinum* infection in cattle following the eating of bones, and with the researches into this condition which ultimately demonstrated the deficiency of calcium-phosphorus in the grazings, a deficiency which the cattle attempted to make good by eating the bones of dead animals in some of which *Cl. botulinum* was present. In Australia, Bennetts and his colleagues have shown that botulism may occur in sheep and cattle by the ingestion of carrion containing the toxin of *Cl. botulinum*. Recently published

articles from South Africa and Australia indicate that the use of a formalinized filtrate of the organism is of value in controlling the occurrence of botulism in these animals. It may be advisable in connexion with *Cl. botulinum* to bear in mind the necessity of ensuring that protection is accorded against all the toxins just as in the case of *Cl. welchii* infections.

Cl. tetani.—Marked progress has been made concerning the recognition, cultivation, and prophylaxis of infection by this organism. The laboratory work of Fildes in encouraging the growth of the organism in recognized form stands out markedly. The use of formalinized toxin or toxoid in the immunization of horses is important, and it is interesting that apparently normal horses have never been shown to possess tetanus antitoxin though they must have many chances of picking up infection throughout their lives, and they thus differ in their reaction to other toxigenic organisms, e.g. *Cl. welchii* and *C. diphtheriæ*. The method of protection of horses against tetanus marks a considerable degree of progress, for though, in some instances, tetanus antitoxin is still used for prophylactic as well as for curative purposes, in districts where the risk of tetanus is well recognized, it is now becoming a common practice to employ active immunization. One dose of potent toxoid will create a considerable degree of active immunity and the formation of antitoxin can often be demonstrated. A second dose, injected a few weeks or months later, causes a rapid and extensive rise in the degree of immunity and the amount of demonstrable antitoxin. Horses so immunized will withstand natural infection probably for years. It is of interest that it is laid down by official regulation that horses used for the purpose of producing antisera must be immunized against tetanus, and that in many serum-producing establishments the toxoid method is that in common use.

It is naturally outside my province to discuss immunization of human beings but in passing it may not be out of place to mention the possibility, in the case of war, of actively immunizing persons likely to be exposed to infection by *Cl. tetani*. As far as horses are concerned it would seem to be of the highest importance to adopt such a procedure.

I would point out in connexion with these remarks on anaerobes that the progress attained has been largely due to co-operation between workers trained in the various sciences, and much has been based on some of the original work of Glenny, Ramon, and others, concerning the methods of diphtheria immunization.

Virus Infections of Animals

I think it can be claimed definitely that work carried out in connexion with virus diseases of animals has a bearing of considerable moment concerning diseases of human beings, caused by similar types of infection. We remember, of course, that one of the oldest recognized diseases caused by a filtrable virus was foot-and-mouth disease.

The production of immunity against virus diseases has advanced considerably of late. The recognition of the presence of virus in the tissues of affected animals has led to the adoption of the use of such infected tissues suitably treated in the production of an active immunity. In this connexion the investigations of Laidlaw and Dunkin, on the prevention of canine distemper, must stand out as classical. We have had ample opportunity during recent years of confirming all their observations.

It has been clearly established that in order to have a strong persisting active immunity set up in a dog, the animal must have access to live virus. I am well aware that this condition does not apply to all virus infections, but it is certainly true of the virus of canine distemper and of some other viruses affecting animals. "Killed" virus, i.e. virus containing tissue treated with formalin, will on injection, give rise to an immunity of an order sufficiently strong to enable the dog to withstand the effects of many infecting doses of fully virulent virus injected up to three to four weeks later. The "killed" virus, however, only produces a transient immunity and unless reinforced, the immunity will fade till within five or six weeks the dog is again in a

highly susceptible condition. A second dose of a similar " killed " virus, injected from three to five weeks after the first, will cause a prolongation of the immunity up to a period of four or five months, but again the immunity fades and the dog again becomes susceptible. If during the period of temporary immunity the animal is exposed to virulent virus, either naturally or by injection, a state of solid, lasting immunity is produced. One of the common methods of immunizing dogs against virus distemper is to inject one dose of " killed " virus followed two or three weeks later by a dose of fully virulent live virus. To ensure that the " killed " virus will set up immunity the tissue used in its preparation must contain a high concentration of virus. Failure to observe this feature results in the production of low-degree immunity or, in many cases, of no demonstrable immunity. A question which has not yet been fully settled is whether the so-called " killed " virus is really dead or is merely inactivated in some manner to such a degree that it fails to infect. All the available tests capable of being applied would indicate that it is really dead, and here I think that the arguments put forward by Bedson in his Presidential address last year apply to the virus of canine distemper in the same measure as to the viruses which he mentioned. Against this may be quoted the occasional case of the dog in which symptoms of true virus infection apparently soon follow the injection of killed virus, and virulent virus is subsequently recovered from the tissues. It has been recorded that viruses may still be alive and virulent in the tissues of apparently immune animals the blood of which contains antibodies. As far as I know, no work on this subject has been carried out in dogs, but it is of interest to note that ferrets infected with virus of low potency may fail to show evidence of infection over a long period and when injected with a virus of high virulence, show typical, severe symptoms of infection within two days, whereas the " normal " susceptible ferret does not manifest evidence of infection, following a similar dose of the same virus, for at least seven or eight days. This would appear to support the contention that a virus may induce a state of tolerance as opposed to immunity and that the tolerance is only such that a " tipping of the balance " will short-cut the original period of incubation.

In the majority of the infections occurring soon after " killed " virus has been injected it has been a fairly simple matter to demonstrate that exposure to infection had occurred at a recent date.

In connexion with distemper virus the question of preservation arises because, of course, in the immunization of dogs against the disease, live, virulent virus is used. Viruses apparently differ considerably in their resistance to external influences. Distemper virus readily dies off when separated from the tissues of the host and much care has to be observed in its preservation outside the animal body. An interesting observation in this connexion was made with fowl-pox virus which is found in the scales which are characteristic of the disease. Provided the scales remain intact, the virus will withstand much rough usage, but the grinding of the scales—with, presumably, the liberation of the virus—results in its early death. I am of the opinion that canine distemper virus soon disappears from infected premises provided that no suspectible animals are present. In this respect the virus of feline enteritis, as shown by Findlay and Hindle, differs considerably, for it is only with the greatest difficulty that premises, fomites, &c., can be rid of infection long after the removal of any susceptible or affected animal. Drying the tissue containing the virus would appear to result in a stable, live product provided that the dried material is not exposed to variation in temperature. It was at one time thought that canine distemper virus, in the form of infected tissue, should be dried to its limit in order to preserve it, but recent work seems to indicate that an optimum amount of water should remain in the dried material in order to ensure its stability over a period.

Formalinized tissue containing virus is being extensively employed in Scotland in the prevention of louping-ill in sheep; the brain, spinal cord, and spleen, of infected sheep are used. It is also being employed in the prevention of rinderpest in some

districts in Africa, the spleen of infected cattle being used. In these diseases, the immunity set up by the " killed " virus is sufficient to protect the animals over the desired period and a further injection of live virus is not considered necessary.

Another point of interest is the alteration of the capability of virus to attack different tissues. The work of Findlay must be regarded as of fundamental importance in this respect. The practical value of the method has been amply illustrated in South Africa, following the work of Alexander and his colleagues. African horse-sickness—a disease in which the virus is present in the circulating blood-stream—caused heavy mortality among imported horses. The former method of immunization was the use of virus and hyper-immune serum. Unfortunately for several reasons, not the least of which was the incidental mortality during immunization, the method could not be regarded as efficient. Alexander was able to " adapt " the virus to the brain of the mouse and after numerous passages from mouse-brain to mouse-brain, succeeded in establishing a virus neurotropic for the mouse which is innocuous for the horse, though retaining its antigenic properties. Up to the present, so far as domesticated animals are concerned, this is the only example of the successful use of this adaptation of viruses for " foreign " tissues. In this connexion it is necessary to remember that a virus which may show affinity for nervous tissue in addition to, say, epithelial tissue, cannot be classified as possessing neurotropic properties. The location of the virus of canine distemper in the brain of the dog is well recognized, but the recovered virus, even if injected directly into the brain of a susceptible dog, still sets up the recognized symptoms of the disease without any nervous complications. If the same virus is injected into the brain of a dog immunized against the virus no symptoms are observed, the dog behaving exactly as if it were exposed to natural infection or as if the virus was injected by the subcutaneous route.

The effect of virus on allied species of animals is of considerable interest. The virus of canine distemper infects the dog, the fox, and animals of the ferret type. (Incidentally, it has been recovered from two outbreaks of distemper in foxes bred in captivity in this country.) The virus recovered from an affected dog will readily set up infection in the ferret, and vice versa, but the same virus may not give rise to symptoms in the fox till it has been passaged in that animal on several occasions. Once the infection has been established in that animal, it apparently infects any susceptible animal—dog, fox, or ferret. Apparently, therefore, the question of tissue response has a bearing on infection. It is of interest to record that for the fox there is a virus which sets up a true encephalomyelitis. Green, working in America, isolated the virus in question. Innes and I have carried out a few experiments with it, in which we have shown that it differs entirely from that giving rise to canine distemper. It fails to infect ferrets and only infects dogs when injected directly into the brain. By this route it infects equally dogs susceptible, or immune, to canine-distemper virus and sets up a train of symptoms associated entirely with the nervous system and differing markedly from those following injection of the canine-distemper virus by any route. As far as I know, this fox-encephalitis virus has not been recovered from dogs in this country. Concerning the immunizing value of canine distemper virus from these animals, live virus from any of them will readily immunize any of the other animals, but it has been definitely shown that " killed " virus of one origin will only with difficulty cause the development of sufficient immunity to resist the effects of live, virulent virus from the same animal source ; it often happens that several doses correctly spaced are required, e.g. immunizing ferrets with virus-containing tissue of dog origin.

The production of immune serum (anti-virus) against viruses affecting domesticated animals is, in many cases, easily accomplished, though with other viruses there appears to be some doubt whether specific antibodies are developed. Thus the immunization and hyperimmunization of dogs against the virus of canine distemper with the production of high-titre antiserum is a comparatively easy procedure. It is

a fairly simple matter to demonstrate the presence of antivirus in dog serum, the methods in common use being the complement-fixation test, the test whereby falling doses of serum are kept in contact with a fixed dose of dried, stable virus for a fixed time before injection into the ferret, and the *in vivo* test in which susceptible dogs are injected with a fixed dose of virus and later with falling doses of serum. In our experience these methods are complementary.

It would be unfair to pass from immunization against canine-distemper virus infection without mentioning the use of hyperimmune serum and virus—a method which is largely used to-day with apparently successful results. It consists in injecting a dose of virulent virus and controlling its effects by the injection of hyperimmune serum. Apparently the amount of serum, provided it is sufficient to prevent the appearance of symptoms of virus infection, is not important. A further method which has possibilities, though it has not yet been fully worked out, is that recorded by Perdrau and Todd, namely, inactivating virus by the action of methylene blue and irradiation. We carried out some experiments on this subject a few years ago and showed that it was possible to alter the virus so that it was no longer infective in large doses but was highly antigenic. Economic difficulties may prevent its being adopted in practice.

One of the most interesting features of virus infection is that of the accompanying infective agents. Concerning canine distemper virus infection, a train of mild symptoms only is set up if secondary organisms are entirely excluded. Many dogs suffer naturally from such a pure infection and in many cases the symptoms may be so mild as to pass unnoticed. One of the gross " pure " complications is involvement of the nervous system—so-called chorea. Usually, however, complications due to invasion of affected tissues with micro-organisms take place, e.g. pneumonia, &c., from *B. bronchisepticus* and streptococci, gastro-enteritis from various Salmonellas, &c. The presence of these complicating micro-organisms has, in the past, led to errors in research results, e.g. *B. bronchisepticus* regarded as the cause of canine distemper. A point on which disagreement still exists is whether these secondary infections can primarily cause disease in the absence of virus. My view is that, occasionally, the organisms may have attained such a degree of virulence that they may, *per se*, set up infection in dogs immune to virus infection. We were able, under experimental conditions, to show that *B. bronchisepticus*, passaged through dogs, on several occasions was capable of setting up infection in dogs we had already immunized against virus infection. It may be noted, in passing, that recent work in Germany (Waldmann) and in Northern Ireland (Lamont and Shanks) indicates that in these countries the same conditions for the production of swine influenza hold good, as in Shope's experiences in America, namely, the association of virus and a strain of the hæmophilus type of organism. In canine distemper, feline enteritis, and some varieties of coryza in poultry, the association of micro-organisms with the virus is well known and is responsible for the essential symptoms associated with these diseases, but on the other hand, contrary to the findings in swine influenza, the viruses themselves can and do cause symptoms of disease.

The subject of viruses cannot be dismissed without reference to the work of Galloway, especially concerning the filtration and measuring of viruses, and that of Burnett concerning the cultivation of viruses on the chorio-allantoic membrane of developing eggs, work which will undoubtedly lead to advance in the study of viruses themselves and methods of immunization against them.

Diseases due to Mineral Deficiencies

A group of diseases now receiving much attention is that associated with mineral deficiencies. There may be a sudden deficiency of a large amount of the mineral available but, on the other hand, the disease process may be gradual, the symptoms appearing over a period while the deficiency lasts. In connexion with these diseases,

the so-called trace elements must be considered concerning their influence on the health of animals, and in their relationship to the occurrence of disease. It would be impossible here to go into this subject to any extent, but I would mention examples of two main conditions.

Milk fever in cows was investigated by Dryerre and Greig in Edinburgh, and was shown to be associated with a sudden fall in the calcium content of the blood. The deficiency may occur quite suddenly, though in some cases there is evidence of an abnormally low content prior to the occurrence of symptoms soon after parturition. The supplying of calcium (by the subcutaneous injection of a soluble solution of calcium, e.g. calcium borogluconate) causes rapid recovery, and it appears that the administration of calcium *per os* for a period prior to parturition may prevent the occurrence of the disease.

Lactation tetany is a disease which occurs suddenly and may appear in cattle soon after being put to graze in the spring, after having been housed for the winter. There is some evidence that the quality and quantity of the grass eaten by the animals may have a bearing on its occurrence. It has been shown that a deficiency of magnesium in the blood is associated with the occurrence of lactation tetany, and here again there may be a sudden drop in the amount present though, in some cases, there is evidently a prolonged period of low magnesium content. The supply of magnesium, in the form of a subcutaneous injection of magnesium sulphate, is often followed by rapid recovery. In some instances low blood content of both calcium and magnesium have been recorded, and the administration of both substances has been found necessary to effect recovery from an attack.

With regard to the more gradual effects of deficiency of minerals I will give three examples. There occurs in young suckling pigs a form of anæmia associated with a deficiency of iron. This deficiency undoubtedly originates in the mother pig and the piglets are born without a sufficiency of reserve iron in their tissues and, further, do not receive a sufficient amount in the milk from the mother. It is a simple matter to correct this deficiency by administering iron to the young pigs by mouth—apparently the iron fed to the lactating mother is not passed on to the suckling piglets.

In some districts in Scotland a disease referred to as " pine " affects cattle and sheep. For its prevention and cure, removal of the animals to other districts for a period of time each year is practised. Though iron was for some time believed to be the deficient mineral and though good results in prevention and cure followed the administration of iron compounds, there is now much evidence that the deficient mineral is really cobalt. Evidently the good effect of the feeding of the iron compounds was not due to the iron, *per se*, but to the traces of cobalt contained in such compounds, the cobalt acting as a catalyst in the assimilation of the iron. Some experiments carried out recently in the South of Scotland strongly support this theory.

In many parts of Britain and in parts of Australia, South America, and India, there exists a disease in lambs and young sheep termed " swayback ", which is characterized by ataxia. Innes, working in this country, demonstrated the pathology of the condition as a demyelination of the white matter of the central nervous system and is of the opinion that histo-pathologically, at least, the disease is akin to Schilder's disease in man. The ætiology of the condition remained obscure for some time. At one time Bennetts, working in South Australia, propounded the theory that the cause was a form of lead-poisoning and gave as evidence the finding that the feeding of a " de-leading " agent—calcium chloride—appeared to prevent its occurrence. Later, he altered his views, chiefly because of the failure of this treatment in some cases and his inability to demonstrate lead in the tissues of affected animals. He then proceeded to examine the tissues of affected lambs more fully and found a gross deficiency of copper. He showed, further, that the tissues of the mothers of the affected lambs were deficient in copper and that there was present a type of anæmia

associated with copper deficiency. Feeding with pure copper sulphate resulted in prevention and cure of the condition, and in this country there is some indication that similar treatment is also effective. While we in this country cannot subscribe entirely to the findings in Australia, especially concerning the specific anæmia accompanying the disease, we are so much impressed by the work carried out in Australia and in this country on the copper deficiency, that a large-scale experiment, to be carried out next spring has been planned, in which, among other things, the value of feeding copper to pregnant sheep in an area in which the disease is endemic, with adequate controls, will be investigated. It is significant that, both in this country and in Australia, the pastures in the affected areas show no deficiency in copper. There is some evidence in this country that, in some affected areas at least, the presence of lead is excessive in the soil and the amount of lead in the tissues of affected animals is considerable.

A vast field for investigation is now being opened up concerning the influence of excess and deficiencies of minerals which exist normally in animals in " trace " amounts, on the occurrence of diseases, specific and otherwise. The good services of the chemist and nutritionist will be essential in any investigations on this subject, which will have, not merely to embrace the establishing of the quantities of minerals in soil, food, tissues, &c., but to be concerned with assimilation of minerals under many varying conditions.

Lymphomatosis in Fowls

Had time permitted it might have been of interest to review the position of our knowledge concerning some of the other diseases of domesticated animals. One could have said much on mastitis in cows and the work carried out on associated streptococci and other micro-organisms by Minett and his school. One would also have liked to consider the position of research into contagious abortion in cattle, especially its relation to human infection, and the use of killed vaccines and chemical compounds in its prevention and control. It also might have proved instructive to review the position concerning the control of tuberculosis in cattle with special reference to the use of different types of tuberculin as a diagnostic agent and the immunizing values of vaccines like B.C.G., &c., which have been studied by Buxton and his colleagues. It would also have been profitable to consider our knowledge on Johne's disease and the value of different types of the agent Johnin in diagnosis. I must content myself to leave these matters to others to deal with on some future occasion. I cannot, however, conclude this address without brief reference to the disease affecting poultry, which is giving rise to such heavy losses throughout practically the whole world. I refer, of course, to " fowl paralysis ", " neurolymphomatosis ", or, as I like to name the condition, " lymphomatosis ".

It was Marek who first described the condition, and in this country Galloway drew attention to its occurrence and McGaughey described the symptoms and lesions. The histo-pathology is now well established, the lesions consisting of accumulations of cells of the lymphoid series, especially in nervous tissue, including the central nervous system and the peripheral nerves. They also occur in other tissues, especially the ovary, where they may give rise to tumour-like bodies of large size. Some difference of opinion exists concerning their invasion of other tissues, but there seems little doubt that masses of such cells may be found in practically all the tissues of affected fowls, including the eye and its appendages. On the whole, little progress has been made concerning our knowledge of this disease during very recent years. We know that certain strains of fowls are more susceptible to the condition than others, that in susceptible strains certain individuals, male and female, apparently give rise to progeny which are highly susceptible to the naturally occurring disease and that the disease itself, or the tendency to develop the disease, is passed from the parent to the offspring through the egg. It is also recognized that the clinical

manifestations of the disease may become eliminated from a flock by continuous breeding from the survivors and that the disease may apparently be introduced into a flock by the importation of stock from an affected source. Usually the disease remains localized to the progeny of the imported stock but it may, at a later date, appear among the progeny of the home stock.

The cause has not yet been established, though there is much evidence that the disease can be set up artificially by the injection of emulsions of affected tissues. The incidence of infection following such injections varies considerably with the stock, but there seems no doubt that transmission can be accomplished. No results have yet been forthcoming following the injection of filtrates of affected tissue emulsions.

At Cambridge there exists a group of fowls which has been inbred for five generations from the survivors of an outbreak of fowl paralysis. For the past three years (i.e. the last three generations) no clinical evidence of the disease has been observed. It was thought that these birds might, by breeding, have developed an immunity of some type. On testing the fifth generation by the injection of affected tissue suspensions, a high incidence of infection occurred ; this is somewhat contrary to what was expected. However, this stock can now be used for a variety of experiments in the knowledge that it will respond well to artificial infection. A noteworthy feature concerning the incidence of this disease is that it is usually accompanied by a high incidence of mortality in apparently non-affected fowls of the same strain, the causes of death being of an indefinite nature but usually involving the genital or alimentary system. It has also been established that microscopical examination of tissues is essential in diagnosing the condition, as the clinical appearance of the fowl, or the macroscopic appearance of the peripheral nerves, is not a sure indication of its presence.

Some recent investigations carried out in Aberdeen and in Cambridge lend support to the view that some infective agent is the root cause of fowl paralysis ; the nature of the infection, if any, is, however, still obscure.

There is a growing feeling among those of us who have studied this disease and made observations on its occurrence and transmission that its cause may be closely linked up with that of tumour-formation generally. For this reason we welcome the information that it may be possible in the near future for intensive work on this and allied diseases in fowls to be undertaken by a group of workers representing various branches of scientific training. From such a concentrated effort not only may the nature of lymphomatosis in fowls be finally settled, but the results may have much bearing on diseases of a somewhat similar nature in the human subject and in domesticated animals.

Conclusion

This address was prepared mainly to indicate the progress of our knowledge of the diseases affecting our domesticated animals. I am fully aware that it is but a sketchy and inadequate contribution, but I feel I may have been able to impress on this Section that, thanks to better training and to the close collaboration of workers in the various branches of science, we are steadily making progress. There is no doubt that every observation properly controlled is a step forward in the study of scientific problems and in the maintenance of a healthy population of both human and animal life.